Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)

1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普適氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)

1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)

1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)

1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)

1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Use the following data wherever necessary :

Charge of electron	$e = 1.6 \times 10^{-19}$ C

The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$

Part A : HKCE examination questions

1. **< HKCE 1980 Paper II - 37 >**

In a β decay, element X, having a half-life of 3 days, decays into a stable element Y. If the initial mass of X is 4 g, what will be the masses of X and Y after 6 days ?

	Mass of X	Mass of Y
A.	0 g	4 g
B.	1 g	3 g
C.	2 g	2 g
D.	3 g	1 g

2. **< HKCE 1981 Paper II - 36 >**

If the three kinds of radiations α, β and γ are arranged in ascending order of their ionization power, their order is
A. α, β, γ
B. α, γ, β
C. β, α, γ
D. γ, β, α

3. **< HKCE 1982 Paper II - 38 >**

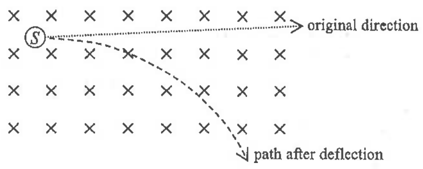
A radioactive substance has a half-life of 10 minutes. Which of the following statements is/are correct ?
(1) All the atoms of the radioactive substance will split into 4 equal parts in 5 minutes.
(2) All the atoms of the radioactive substance will decay completely in 20 minutes.
(3) All the atoms of the radioactive substance will decay within 10 minutes.
A. (1) only
B. (2) only
C. (3) only
D. None of them

4. **< HKCE 1983 Paper II - 36 >**

The half-life of a radioactive substance is 8 hours. Its initial mass is 3 g. Find the amount of the radioactive substance remaining unchanged after 24 hours.
A. 0.375 g
B. 0.75 g
C. 1 g
D. 2 g

5. **< HKCE 1984 Paper II - 36 >**

S is a radioactive source which emits radiation as it decays. If all the radiation emitted is bent by a magnetic field in the direction shown, then the radiation consists of
A. α and γ only
B. β and γ only
C. α only
D. β only



6. **< HKCE 1985 Paper II - 45 >**

The corrected count rate of a sample of radioactive material was measured on the first day of each month. The readings on July 1 and September 1 are 0.8 and 0.2 counts per second respectively. What is the half-life of the radioactive material ?
A. 7 days
B. 16 days
C. 31 days
D. 46 days

7. **< HKCE 1986 Paper II - 35 >**

The speeds of X-rays, γ rays and β rays in air are denoted by v_X, v_γ and v_β respectively. Which of the following is true ?
A. $v_X > v_\gamma > v_\beta$
B. $v_X < v_\gamma < v_\beta$
C. $v_X = v_\gamma = v_\beta$
D. $v_X = v_\gamma > v_\beta$

8. **< HKCE 1987 Paper II - 39 >**

Which of the following about α radiation is/are correct ?
(1) The mass of an α particle is about four times that of a proton.
(2) It has a stronger ionizing power than β radiation.
(3) It has a greater penetration power than γ radiation.
A. (1) only
B. (2) only
C. (1) & (2) only
D. (2) & (3) only

9. **< HKCE 1987 Paper II - 38 >**

Which of the following descriptions of the half-life of a sample of radioactive isotope is/are correct ? The half life is
(1) the time taken for the mass of the sample to fall to half of its initial value.
(2) the time taken for the activity of the sample to fall to half of its initial value.
(3) half of the time taken for the sample to decay completely.
A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

10. **< HKCE 1988 Paper II - 39 >**

The activity of a radioactive source falls to $\frac{1}{8}$ of its original value in 24 minutes. The half-life of the source is
A. 3 min.
B. 6 min.
C. 8 min.
D. 72 min.

11. < HKCE 1989 Paper II - 40 >

A radioactive source has a half-life of 22 years. After 66 years, what fraction of the source remains undecayed ?

A. $\frac{1}{3}$

B. $\frac{1}{6}$

C. $\frac{1}{8}$

D. $\frac{1}{9}$

12. < HKCE 1990 Paper II - 40 >

In an experiment to measure the half-life of a radioactive isotope in a place where the background count rate is 20 counts per minute, the following results are recorded :

Time / minute	0	2	4	6	8	10	12
Total count rate / counts per minute	116	96	80	69	58	50	44

The half-life is about

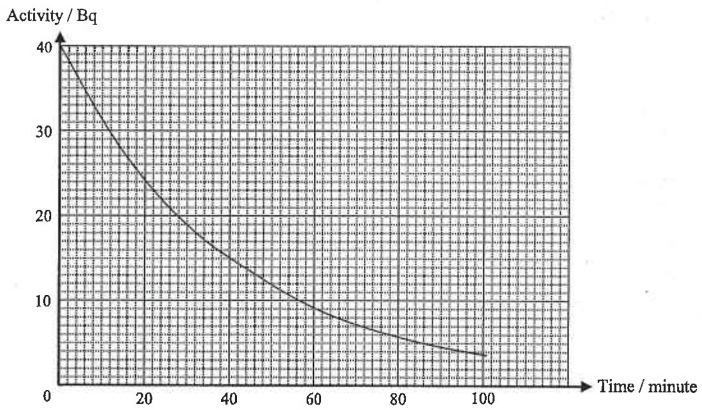
A. 4 min.

B. 6 min.

C. 8 min.

D. 10 min.

13. < HKCE 1991 Paper II - 41 >



The activity of a radioactive source is recorded on a graph as shown above. What is the half-life of the source ?

A. 20 min.

B. 24 min.

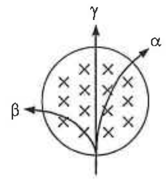
C. 28 min.

D. 32 min.

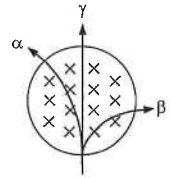
14. < HKCE 1992 Paper II - 40 >

Which of the following diagrams correctly shows the deflections of α, β and γ rays in a uniform magnetic field pointing into the paper ?

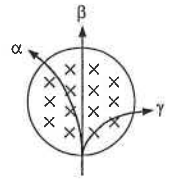
A.



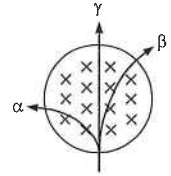
B.



C.



D.



15. < HKCE 1993 Paper II - 39 >

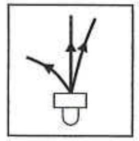
Which of the following signs is used to indicate radioactive material ?

A.

B.

C.

D.



16. < HKCE 1994 Paper II - 38 >

Arrange α, β and γ radiation in ascending order of their ionizing powers :

A. α , β , γ

B. β , γ , α

C. γ , α , β

D. γ , β , α

17. < HKCE 1994 Paper II - 41 >

The activity of a radioactive source drops from 640 Bq to 40 Bq in 2 hours. Find the half-life of the source.

A. 7.5 min.

B. 15 min.

C. 24 min.

D. 30 min.

18. < HKCE 1995 Paper II - 26 >

Which of the following cannot travel through a vacuum ?

A. β particles

B. Infra-red

C. Microwaves

D. Ultrasonics

19. **< HKCE 1995 Paper II - 39 >**

Which of the following statements about X-rays is/are correct ?

(1) X-rays consist of fast moving electrons.
(2) X-rays can blacken photographic films.
(3) X-rays can be used to detect weapons hidden in luggage.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

20. **< HKCE 1996 Paper II - 39 >**

Which of the following can be deflected by both an electric field and a magnetic field ?

(1) α particles
(2) β particles
(3) γ rays

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

21. **< HKCE 1996 Paper II - 41 >**

The activity of a radioactive isotope falls to $\frac{1}{16}$ of its initial value in one hour. Find the half-life of the isotope.

A. 3.75 minutes
B. 7.5 minutes
C. 10 minutes
D. 15 minutes

22. **< HKCE 1997 Paper II - 39 >**

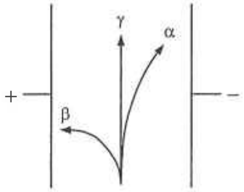
Which of the following statements about β particles is **incorrect** ?

A. β particles can be stopped by a piece of paper.
B. β particles can be deflected by a magnetic field.
C. β particles can blacken photographic films.
D. β particles can travel through a vacuum.

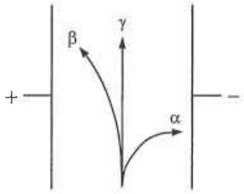
23. **< HKCE 1998 Paper II - 40 >**

Which of the following diagrams correctly shows the directions in which α, β and γ radiations are deflected in a uniform electric field produced by two charged metal plates ?

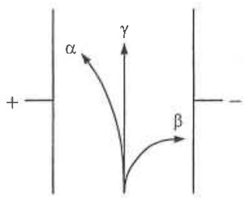
A.



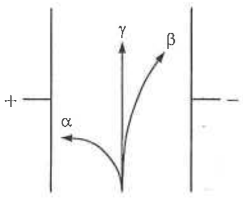
B.



C.



D.



24. **< HKCE 1999 Paper II - 38 >**

Which of the following statements about α particles is **incorrect** ?

A. α particles can be stopped by a piece of paper.
B. α particles can blacken photographic films.
C. α particles have a range of several centimetres in air.
D. α particles cannot travel through a vacuum.

25. **< HKCE 1999 Paper II - 26 >**

An insulated metal sphere carries positive charges. Which of the following will discharge the sphere ?

(1) bringing an alpha source near the sphere
(2) touching the sphere momentarily with a finger
(3) bringing a negatively charged metal rod near the sphere (but without touching it)

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

26. **< HKCE 1999 Paper II - 37 >**

The background count rate recorded by a Geiger-Muller counter is 80 counts per minute. When a radioactive source is placed closely in front of the Geiger-Muller tube, the count rate recorded is 560 counts per minute. After 6 hours, the count rate drops to 140 counts per minute. Find the half-life of the source.

A. 45 minutes
B. 1 hour
C. 1 hour 30 minutes
D. 2 hours

27. **< HKCE 2000 Paper II - 40 >**

Which of the following statements about α particles and γ rays is correct ?

A. Both of them are transverse waves.
B. Both of them can be deflected by a magnetic field.
C. Both of them have strong ionizing power.
D. Both of them can travel through a vacuum.

28. **< HKCE 2000 Paper II - 41 >**

Which one of the following is **not** a safety precautions for handling radioactive sources ?

A. Users should not eat or drink when handling radioactive sources.
B. Users should wear gloves for handling radioactive sources.
C. Radioactive sources should not be held close to the eye for visual examination.
D. Radioactive sources should be stored in wooden boxes after use.

29. **< HKCE 2001 Paper II - 40 >**

The initial activity of a radioactive isotope is 2000 Bq. After 4 hours, the activity of the isotope drops to 125 Bq. Find the half-life of the isotope.

A. 15 minutes
B. 30 minutes
C. 48 minutes
D. 60 minutes

30. **< HKCE 2002 Paper II - 41 >**

Which of the following particles **cannot** be deflected by a magnetic field ?

A. α-particles
B. β-particles
C. neutrons
D. protons

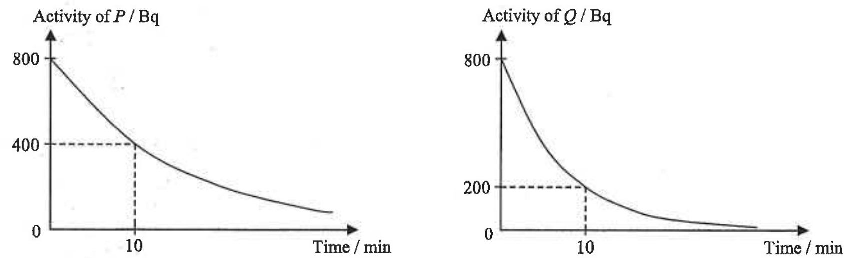
31. **< HKCE 2003 Paper II - 40 >**

Which of the following statements about α particles and γ rays is/are correct ?

(1) They can both be deflected by a magnetic field.
(2) α particles have a stronger ionizing power than γ rays.
(3) They are emitted with almost the same speed in radioactive decay.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

32. **< HKCE 2003 Paper II - 41 >**



The figures above show the variation of the activities of two radioactive sources P and Q with time. Find the ratio of the half-life of P to that of Q.

A. 1 : 1
B. 1 : 2
C. 2 : 1
D. 4 : 1

33. **< HKCE 2004 Paper II - 41 >**

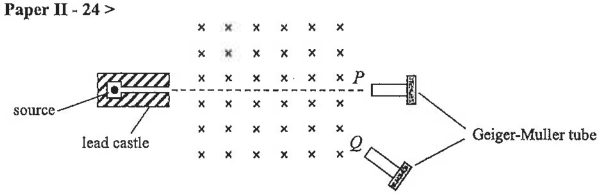
Different absorbers are placed in turn between a radioactive source and a Geiger-Muller tube. Three readings are taken for each absorber. The following data are obtained :

Absorber	Count rate / s^{-1}		
–	200	205	198
Paper	197	202	206
5 mm aluminium	112	108	111
25 mm lead	60	62	58
50 mm lead	34	36	34

What type(s) of radiation does the source emit ?

A. β only
B. γ only
C. β and γ only
D. α, β and γ

34. **< HKCE 2005 Paper II - 24 >**



A radioactive source is placed in front of a uniform magnetic field pointing into the paper as shown above. If a high count rate is recorded at positions P and Q, what kinds of radiation have been detected ?

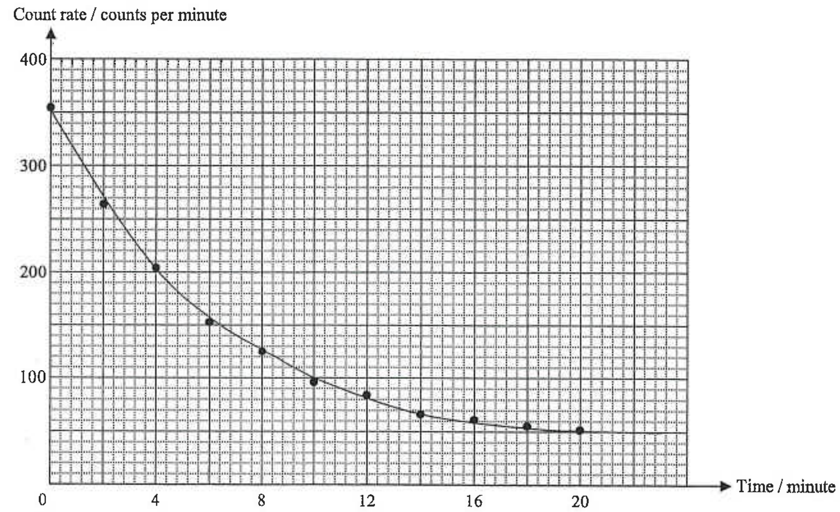
	P	*Q*
A.	γ	α
B.	γ	β
C.	β	α
D.	β	γ

35. **< HKCE 2006 Paper II - 42 >**

A radioisotope X has a half-life of 2 days while another radioisotope Y has a half-life of 1 day. Initially there are N undecayed atoms of X and 8 N undecayed atoms of Y. After how many days will X and Y have the same number of undecayed atoms ?

A. 3 days
B. 4 days
C. 6 days
D. 8 days

36. **< HKCE 2007 Paper II - 24 >**



Susan performs an experiment in which a radioactive source is placed closely in front of a GM counter. The graph shows the variation of count rate with time. What is the half-life of the radioactive substance ?

A. 4 minutes
B. 5 minutes
C. 8 minutes
D. 10 minutes

37. **< HKCE 2007 Paper II - 26 >**

Some dangerous substances are stored in a metal container inside a wooden box as shown in the figure. What metal should be used for the container and what type of substance is stored ?

	Metal used	Type of substance stored
A.	Iron	Radioactive
B.	Iron	Flammable
C.	Lead	Radioactive
D.	Lead	Flammable

38. **< HKCE 2008 Paper II - 24 >**

Which of the following descriptions about the half-life of a radioactive substance in a sample is correct ?
A. It is equal to half of the time for all the radioactive nuclei of the substance to decay.
B. It is equal to half of the time for a radioactive nucleus of the substance to decay.
C. It is equal to the time for the sample to reduce its mass by half.
D. It is equal to the time for half of the radioactive nuclei of the substance to decay.

39. **< HKCE 2008 Paper II - 25 >**

Which of the following actions will maximise a person's exposure to radiation ?
A. Using a GM tube and counter to measure the background radiation in laboratory.
B. Eating food that has been sterilised by exposure to gamma radiation.
C. Listening to radio.
D. Going for a flight to a distant place in a high-flying aeroplane.

40. **< HKCE 2008 Paper II - 27 >**

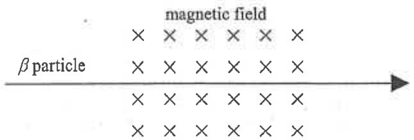
Which of the following statements about β particles is correct ?
A. β particles carry positive charge.
B. β particles can be deflected by a magnetic field.
C. β particles cannot be deflected by an electric field.
D. β particles can be stopped by a sheet of paper.

41. **< HKCE 2009 Paper II - 26 >**

The half-life of a radioactive sample is 15 hours. The initial count rate recorded is 1000 counts per minute. After 15 hours, the count rate recorded becomes 528 counts per minute. What is the background count rate ? (Measured in counts per minute.)
A. 25
B. 28
C. 50
D. 56

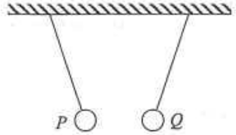
42. **< HKCE 2010 Paper II - 45 >**

In the figure, a β particle enters a region with a magnetic field pointing into paper and an electric field of unknown direction. The β particle has no deflection. What is the direction of the electric field ?

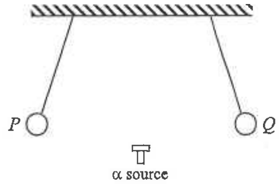


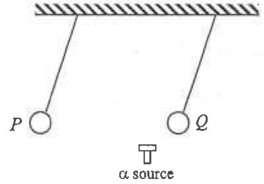
A. ←
B. →
C. ↑
D. ↓

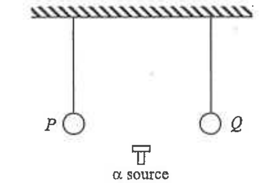
43. **< HKCE 2010 Paper II - 24 >**

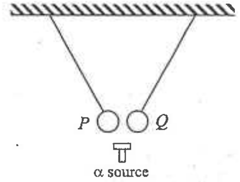


In the figure above, two charged metal balls P and Q are hung by insulating threads. P is positively charged while Q is negatively charged. An α source is put near the balls without touching them. Which of the following figures shows the situation after a period of time ?

A.


B.


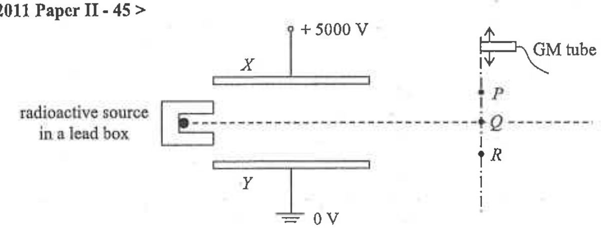
C.


D.


44. **< HKCE 2010 Paper II - 23 >**

The initial activity of a sample of radioisotope is 960 Bq. Its activity drops to 240 Bq in 2 minutes. How much more time would be required for its activity to become 30 Bq ?
A. 2 minutes
B. 3 minutes
C. 4 minutes
D. 5 minutes

45. **< HKCE 2011 Paper II - 45 >**



The figure shows a radioactive source placed near two parallel metal plates X and Y that are connected to a power supply. When a GM tube is moved along the dotted line (– · – · –), the count rate shows a significant increase at P and Q respectively. Which of the following statements is correct when a magnetic field pointing out of paper is applied between X and Y ?
A. The count rate at P decreases and the count rate at Q remains the same.
B. The count rates at P and Q remain the same.
C. The count rate at P decreases and the count rates at Q and R increase.
D. The count rates at P, Q and R are equal.

46. **< HKCE 2011 Paper II - 22 >**

Which of the following statements about α, β and γ radiations is **incorrect** ?

A. Only γ radiation can travel through a vacuum.
B. α radiation can be stopped by an aluminium plate of 5 mm thick.
C. β particles are fast moving electrons.
D. γ radiation can blacken a photographic film.

47. **< HKCE 2011 Paper II - 23 >**

A radioactive source is put in front of a GM tube. The initial count rate is 1050 counts per minute. It is known that the half-life of the source is 4 hours and the background count rate is 50 counts per minute. What is the most likely count rate after 8 hours ?

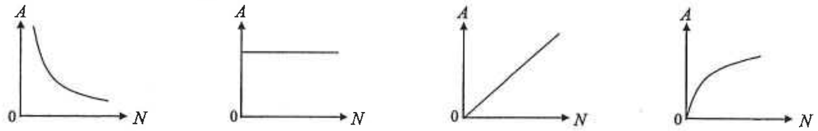
A. 50 counts per minute
B. 125 counts per minute
C. 250 counts per minute
D. 300 counts per minute

Part B : HKAL examination questions

48. **< HKAL 1980 Paper I - 32 >**

Which of the graphs below correctly shows the variation of the activity A of a radioactive sample with the number N of the undecayed nuclei in the sample ?

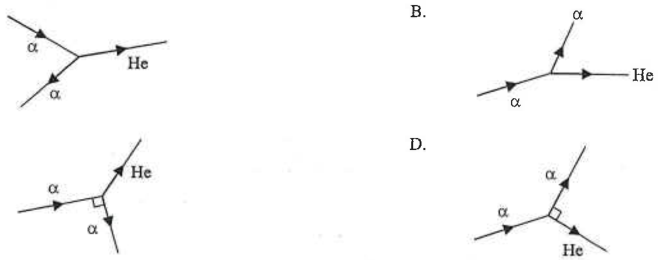
A. B. C. D.



49. **< HKAL 1984 Paper I - 33 >**

An alpha particle (α) makes a collision with a helium nucleus (He) in a cloud chamber. Which of the following diagrams best represents the probable set of tracks ?

A. B. C. D.

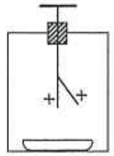


50. **< HKAL 1985 Paper I - 31 >**

Proactinium decays with a half-life of 72 s. The value of the decay constant is

A. 9.6×10^{-3} s.
B. 9.6×10^{-3} s^{-1}.
C. 0.014 s^{-1}.
D. 49.9 s.

51. **< HKAL 1985 Paper I - 34 >**



A dish containing an alpha-source is placed inside a gold leaf electroscope. If the gold-leaf is originally positively charged, what will happen to it after a few minutes ?

A. It will increase in divergence.
B. It will increase in divergence and then decrease.
C. It will collapse.
D. It will collapse and then re-diverge.

52. **< HKAL 1988 Paper I - 44 >**

An alpha-source originally consisted entirely of the element polonium. After the emission of an α-particle, each polonium nucleus becomes a lead nucleus. At the end of two years, the source was found to contain 98% lead and 2% polonium. What is the composition of the sample at the end of one year ?

A. 25% lead, 75% polonium.
B. 50% lead, 50% polonium.
C. 75% lead, 25% polonium.
D. 86% lead, 14% polonium.

53. **< HKAL 1990 Paper I - 48 >**

A radioactive source is placed in front of a GM counter. Various absorbers are placed between the source and the GM counter and the count-rate recorded. The following results were obtained :

Absorber	Counts per minute
no absorber	712
a sheet of paper	504
5 mm thick aluminium sheet	496
25 mm thick lead block	218

From the above result, the radiation(s) emitted by the source is/are

A. α and γ rays only
B. β and γ rays only
C. α rays only
D. β rays only

54. **< HKAL 1992 Paper I - 45 >**

A radioactive source consists of a mixture of two radioisotopes P and Q. The half-life of P is 1 hour and that of Q is 2 hours. Both P and Q have stable daughter nuclei. The initial corrected count rate due to the mixture is 600 counts per minute. After 4 hours, the corrected count rate drops to 60 counts per minute. What was the initial count rate due to P only ?

A. 200 counts per minute.
B. 360 counts per minute.
C. 400 counts per minute.
D. 480 counts per minute.

55. **< HKAL 1994 Paper IIA - 44 >**

A GM counter is placed in front of an α-source and a count rate of 120 counts per minute is recorded. After a time equal to the half-life of the α-source, the count rate drops to 64 counts per minute. If a 5 mm thick lead sheet is inserted between the α-source and the detector, the count rate would probably be

A. 0 counts per minute.
B. 4 counts per minute.
C. 8 counts per minute.
D. 16 counts per minute.

56. **< HKAL 1996 Paper IIA - 44 >**

A counter is placed near a radioactive source that has a half-life of 1 hour. The counter registers 100 counts per minute at noon and 80 counts per min at 1 p.m. The expected count rate at 3 p.m. on the same day should be

A. 50 c.p.m.
B. 55 c.p.m.
C. 60 c.p.m.
D. 65 c.p.m.

57. **< HKAL 1998 Paper IIA - 41 >**

The activity of a sample of radioisotopes decreases to $\frac{1}{3}$ of its initial value in 12 s. How much more time is needed for the activity to decrease to $\frac{1}{9}$ of its initial value ?

A. 4 s
B. 8 s
C. 12 s
D. 16 s

58. **< HKAL 2000 Paper IIA - 44 >**

A radioactive source emits both α and γ radiation. A GM counter placing close to and in front of the source records a count rate of 500 counts per minute. The background count rate is 50 counts per minute. Three different materials are placed in turn between the source and the counter. The following results are obtained.

Material	Recorded count rate / counts per minute
(Nil)	500
Cardboard	x
1 mm of aluminium	y
5 mm of lead	z

Which of the following is a suitable set of values for x, y and z ?

	x	y	z
A.	350	350	150
B.	350	150	50
C.	350	150	0
D.	150	150	50

59. **< HKAL 2001 Paper IIA - 45 >**

The table gives the corrected count rate (in counts per minute) from three samples of radioisotopes at three different times.

Isotopes	0 min	20 min	40 min
X	480	243	119
Y	135	32	9
Z	168	118	93

From the above result, it can be concluded that

(1) X produces the most penetrating radiation.
(2) Y has the largest decay constant.
(3) Z has the longest half-life.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

60. **< HKAL 2001 Paper IIA - 42 >**

The activity of a radioactive sample was 70 Bq at time t = 5 minutes and 49 Bq at t = 10 minutes. What is its activity at time t = 0 ?

A. 112 Bq
B. 100 Bq
C. 95 Bq
D. 91 Bq

61. **< HKAL 2003 Paper IIA - 44 >**

A nuclide in a radioactive sample has a probability of 10^{-6} to decay in one second. What is the approximate half-life of the sample ?

A. 1 day
B. 1 week
C. 1 month
D. 1 year

62. **< HKAL 2004 Paper IIA - 42 >**

The activity of a radioactive sample is 1.0×10^6 Bq. The half-life of the sample is 5.3 years. Estimate the number of nuclei in the sample that decay in the first day.

A. 5.2×10^2
B. 3.2×10^8
C. 8.6×10^{10}
D. It cannot be estimated as the initial number of nuclei in the sample is not given.

63. **< HKAL 2005 Paper IIA - 24 >**

The activity of a radioactive source depends on

(1) the number of active nuclei in the source
(2) the half-life of the source
(3) the nature of the nuclear radiation emitted by the source

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

64. **< HKAL 2006 Paper IIA - 24 >**

Some typical radiation doses are given as follows :

	Radiation dose
Watching television	0.005 mSv / hr for watching every day in a year
Flying in an aircraft	0.001 mSv / hr
X-ray check	0.020 mSv each time

Arrange the following in ascending order of total radiation dose in one year.

(1) Watching television for 4 hours every day
(2) Travelling on an aircraft for 10 hours every month
(3) Taking X-ray check every 6 months

A. (1), (2), (3)
B. (2), (1), (3)
C. (1), (3), (2)
D. (3), (1), (2)

65. **< HKAL 2006 Paper IIA - 23 >**

Which of the following gives the correct interpretation of the decay constant of a radioactive substance ?
A. It is the rate of disintegrations of the substance.
B. It is the number of disintegrations of the substance occurring on one half-life of the substance.
C. It is the fraction of the active nuclei that undergoing decay in one second.
D. It is equal to the reciprocal of the half-life of the substance.

66. **< HKAL 2007 Paper IIA - 24 >**

Radioactive source P consists of 64×10^{12} active nuclei. Another source Q consists of 8×10^{12} active nuclei. The half-lives of P and Q are 2 days and 3 days respectively. After how long will the number of active nuclei in the two sources be equal ? (Assume that the daughter nuclides of both P and Q are stable.)
A. 6 days
B. 9 days
C. 12 days
D. 18 days

67. **< HKAL 2011 Paper IIA - 43 >**

Radioactive nuclides X and Y have half-lives 2 hours and 4 hours respectively. The decay of both nuclides gives stable daughter nuclides. Initially samples P and Q contain equal number of atoms of nuclide X and nuclide Y respectively. Which of the following statements are correct ?
(1) The initial activity of sample P is higher than that of sample Q.
(2) After 8 hours, sample P contains more active nuclei than sample Q.
(3) After 8 hours, the chance of a nucleus of X in sample P decaying in the next second is greater than that of a nucleus of Y in sample Q.
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

68. **< HKAL 2012 Paper IIA - 44 >**

The activity of a radioisotope is 250 Bq at time $t = 0$ and 54 Bq at $t = 30$ min. What is its activity at $t = 10$ min ?
A. 130 Bq
B. 150 Bq
C. 185 Bq
D. It cannot be found as its half-life is not given.

69. **< HKAL 2013 Paper IIA - 45 >**

Arrange the following lengths in ascending order of magnitudes.
(1) range of α-particles in air
(2) grating spacing of a typical diffraction grating used in a school laboratory
(3) wavelength of ultra-violet radiation
A. (1), (2), (3)
B. (1), (3), (2)
C. (3), (1), (2)
D. (3), (2), (1)

70. **< HKAL 2013 Paper IIA - 43 >**

The initial activity of two radioactive sources, X and Y, are the same. Both X and Y decay to give stable daughter nuclei. The ratio of the activity of X to that of Y after 12 hours is 4 : 1. If the half-life of X is 6 hours, what is the half-life of Y ?
A. 1.5 hours
B. 2 hours
C. 3 hours
D. 12 hours

Part C : HKDSE examination questions

71. **< HKDSE Sample Paper IA - 35 >**

On which of the following does the activity of a radioactive source depend ?
(1) the nature of the nuclear radiation emitted by the source
(2) the half-life of the source
(3) the number of active nuclei in the source
A. (1) only
B. (2) only
C. (1) & (2) only
D. (2) & (3) only

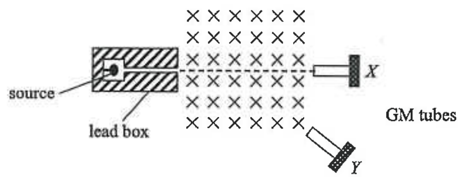
72. **< HKDSE Sample Paper IA - 36 >**

Different absorbers are placed in turn between a radioactive source and a Geiger-Muller tube. Three readings are taken for each absorber. The following data are obtained :

Absorber	Count rate / s^{-1}		
–	200	205	198
Paper	197	202	206
5 mm aluminium	112	108	111
25 mm lead	60	62	58
50 mm lead	34	36	34

What type(s) of radiation does the source emit ?
A. β only
B. γ only
C. β and γ only
D. α, β and γ

73. **< HKDSE Practice Paper IA - 35 >**



A radioactive source is placed in front of a uniform magnetic field pointing into the paper as shown above. The count rates recorded by the GM tubes at X and Y are 101 counts per minute and 400 counts per minute respectively. Which of the following deductions must be correct ?
A. The source does not emit α radiations.
B. The source emits β radiations.
C. The source emits γ radiations.
D. The background count rate is about 100 counts per minute.

74. < HKDSE Practice Paper IA - 34 >

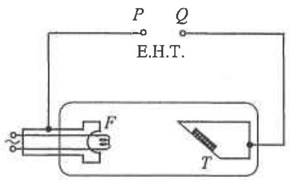
Which of the following statements about α and β particles is/are correct ?
(1) The mass of an α particle is greater than that of a β particle.
(2) α particles have a stronger penetrating power than β particles.
(3) An α source can discharge a positively charged metal sphere nearby.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

75. < HKDSE 2012 Paper IA - 35 >

A certain radioactive isotope X has a half-life of 20 hours. After a time interval of 10 hours, what is the approximate fraction (f) of a sample of the radioactive isotope X remaining ?
A. $\frac{1}{4} \le f \le \frac{1}{2}$
B. $f = \frac{1}{2}$
C. $\frac{3}{4} > f > \frac{1}{2}$
D. $f > \frac{3}{4}$

76. < HKDSE 2012 Paper IA - 34 >

The figure shows a schematic diagram of an X-ray tube in which the filament F and the metal target T are connected to terminals P and Q of an E.H.T. Which statement is correct ?



A. P is the positive terminal and X-rays are emitted from T.
B. P is the positive terminal and X-rays are emitted from F.
C. Q is the positive terminal and X-rays are emitted from T.
D. Q is the positive terminal and X-rays are emitted from F.

77. < HKDSE 2013 Paper IA - 35 >

Polonium-210 is a pure α-emitter with a half-life of 140 days and it will decay into lead, which is stable. Initially there is a sample containing 420 mg of pure polonium-210. Estimate the mass of polonium-210 left after 70 days.
A. 315 mg
B. 297 mg
C. 210 mg
D. 105 mg

78. < HKDSE 2014 Paper IA - 32 >

A GM counter is placed close to and in front of a radioactive source which emits both α and γ radiations. The count rate recorded is 450 counts per minute while the background count rate is 50 counts per minute. Three different materials are placed in turn between the source and the counter. The following results are obtained.

Material	Recorded count rate / counts per minute
(Nil)	450
cardboard	x
1 mm of aluminium	y
2 mm of lead	z

Which of the following is the most suitable set of values for x, y and z ?

	x	y	z
A.	300	300	100
B.	300	100	50
C.	100	100	0
D.	100	50	50

79. < HKDSE 2015 Paper IA - 32 >

Some factories make use of radioactive source for manufacturing. Workers are required to wear clothes with film badges to measure the dosage of radiation received over a period of time. Which type of radiation below CANNOT be monitored by the film badges ?
A. α-radiation
B. β-radiation
C. γ-radiation
D. X-rays

80. < HKDSE 2016 Paper IA - 32 >

Which of the following statements about ionizing radiations is/are correct ?
(1) The ionizing power of α-particles is much stronger than that of β-particles.
(2) γ-radiation can be completely shielded by a 10 cm thick concrete wall.
(3) Ionizing radiations α, β and γ all undergo deflection in an electric field.
A. (1) only
B. (1) & (2) only
C. (1) & (3) only
D. (2) & (3) only

81. < HKDSE 2016 Paper IA - 33 >

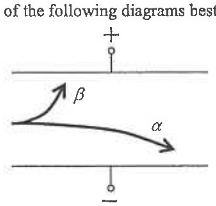
Two radionuclides X and Y are of half-lives 3 hours and 4 hours respectively and initially there are N_X and N_Y undecayed nuclei respectively. After 24 hours, the number of undecayed nuclei of both nuclides becomes the same. Find $N_X : N_Y$.
A. 8 : 1
B. 4 : 3
C. 4 : 1
D. 2 : 1

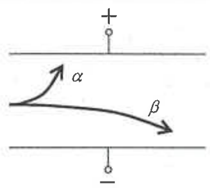
82. < HKDSE 2017 Paper IA - 32 >

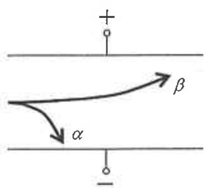
Which of the following statements about particles β and γ rays is correct ?
A. Only β particles can ionize air particles.
B. Only γ rays can travel through vacuum.
C. Both of them can be detected by a photographic film.
D. Both of them carry charge.

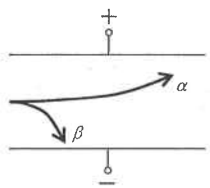
83. < HKDSE 2017 Paper IA - 31 >

Which of the following diagrams best shows the deflection of α and β particles in an uniform electric field in vacuum ?

A.


B.


C.


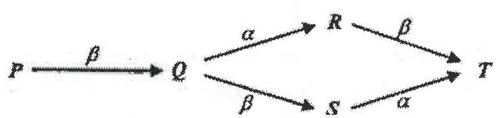
D.


84. <HKDSE 2019 Paper IA-31>

85. <HKDSE 2020 Paper IA-30>

The background count rate in an experiment is determined using a GM counter. Four readings of the count rate in each minute are taken. Which set of readings below is the most probable ?

	1st minute	2nd minute	3rd minute	4th minute
A.	5	62	8	69
B.	40	40	40	40
C.	60	50	30	20
D.	29	26	31	35



HKBAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

M.C. Answers

1. B	11. C	21. D	31. B	41. D
2. D	12. B	22. A	32. C	42. D
3. D	13. C	23. A	33. C	43. C
4. A	14. B	24. D	34. B	44. B
5. D	15. B	25. C	35. C	45. A
6. C	16. D	26. D	36. A	46. A
7. D	17. D	27. D	37. C	47. D
8. C	18. D	28. D	38. D	48. C
9. B	19. D	29. D	39. D	49. D
10. C	20. C	30. C	40. B	50. B

51. C	61. B	71. D	81. C
52. D	62. C	72. C	82. C
53. A	63. C	73. B	83. A
54. D	64. C	74. C	84. D
55. C	65. C	75. C	85. D
56. D	66. D	76. C	
57. C	67. B	77. B	
58. A	68. B	78. A	
59. D	69. D	79. A	
60. B	70. C	80. A	

M.C. Solution

1. B

Mass of X : $4\text{ g} \xrightarrow{3\text{ days}} 2\text{ g} \xrightarrow{3\text{ days}} 1\text{ g}$

Mass of Y : $4 - 1 = 3\text{ g}$

2. D

Ionization power : $\alpha > \beta > \gamma$

In ascending order : γ , β , α

3. D

× (1) Decay does not mean splitting of the atoms.

× (2) In 20 minutes, that is, 2 half-lives, there is still 25% of radioactive atoms left.

× (3) Half-life is the time taken for half of the number of radioactive atoms to decay.

4. A

$3 \xrightarrow{8\text{ hours}} 1.5 \xrightarrow{8\text{ hours}} 0.75 \xrightarrow{8\text{ hours}} 0.375$

After 24 hours, the mass remaining unchanged is 0.375 g

5. D

By using Left-hand rule :

Direction of magnetic field is into paper and direction of magnetic force is downward ⇒ Direction of I is towards the left

As direction of I is opposite to velocity ⇒ the radiation carries (–) charge ⇒ β radiation

6. C

Corrected count rate : $0.8 \longrightarrow 0.4 \longrightarrow 0.2$

As in between July 1 and September 1, there is 62 days. $\therefore$ Half-life = $\frac{62}{2} = 31$ days

7. D

X-ray and γ-ray are both electromagnetic waves $\therefore$ they travel with the speed of light

β-particles are fast moving electrons, but not electromagnetic waves.

β-particles travel with a speed less than that of light.

8. C

✓ (1) An α-particle consists of 2 protons and 2 neutrons, and mass of proton and neutron is nearly the same.

✓ (2) ionizing power : $\alpha > \beta > \gamma$

× (3) α-particles have shortest range in air ⇒ weakest penetrating power

9. B

× (1) The product of decay also carries mass, thus the total mass of the sample should remain unchanged.

✓ (2) Half-life is the time taken for the activity to drop to half of the initial value.

× (3) It takes 1 half-life for half of the number of undecayed nuclei to decay,
but it does not mean another half is to be decayed in the next half-life.

10. C

$1 \longrightarrow \frac{1}{2} \longrightarrow \frac{1}{4} \longrightarrow \frac{1}{8}$

$\therefore$ Half-life = $\frac{24}{3}$ = 8 min.

11. C

$1 \xrightarrow{22\text{ years}} \frac{1}{2} \xrightarrow{22\text{ years}} \frac{1}{4} \xrightarrow{22\text{ years}} \frac{1}{8}$

After 66 years, the fraction of the source remains undecayed is $\frac{1}{8}$

12. B

Time / minute	0	2	4	6	8	10	12
Corrected count rate / cpm	96	76	60	49	38	30	24

As the initial corrected count rate (96 cpm) reduces to about half (48 cpm) in 6 minutes

∴ half-life is about 6 minutes.

13. C

As activity drops from 40 Bq to 20 Bq in 28 minutes ∴ half-life = 28 min

14. B

By using Left-hand rule :

① magnetic force on α which is positive is towards the left

② magnetic force on β which is negative is towards the right

Thus, α is deflected to the left while β is deflected to the right.

As α is much heavier, the degree of deflection of α is much smaller than that of β.

15. B

It is a symbol for all types of radioactive substances.

16. D

Ionizing power : $\gamma < \beta < \alpha$

17. D

$640 \xrightarrow{\times\frac{1}{2}} 320 \xrightarrow{\times\frac{1}{2}} 160 \xrightarrow{\times\frac{1}{2}} 80 \xrightarrow{\times\frac{1}{2}} 40$

∴ Half-life $= \frac{2\text{ hours}}{4} = 0.5$ hours $= 30$ min.

18. D

✓ A. β-particles are particles that can travel in vacuum

✓ B. Infra-red is a type of electromagnetic waves that can travel in vacuum

✓ C. Microwave is a type of electromagnetic waves that can travel in vacuum

× D. Ultrasonics are sound waves with frequency > 20000 Hz, sound waves cannot travel in vacuum.

19. D

× (1) X-rays is a transverse wave, they do not consist of any particles.

✓ (2) X-rays can affect films, and be detected by films.

✓ (3) X-rays are used in airport to detect weapons in luggage.

20. C

Charged particles can be deflected by both a magnetic field and an electric field.

α is (+)-charged and β is (–)-charged, they can be deflected; γ is neutral, it cannot be deflected.

21. D

$1 \xrightarrow{\times\frac{1}{2}} \frac{1}{2} \xrightarrow{\times\frac{1}{2}} \frac{1}{4} \xrightarrow{\times\frac{1}{2}} \frac{1}{8} \xrightarrow{\times\frac{1}{2}} \frac{1}{16}$

∴ Half-life $= \frac{60}{4} = 15$ min.

22. A

× A. β particles can penetrate through paper but stopped by a thin sheet of aluminium.

✓ B. β particles are (–)-charged particles ⇒ deflected by *B*-field

✓ C. β particles are radiation, they can blacken films and be detected.

✓ D. β are particles, thus they can travel in vacuum.

23. A

α is (+) charged, it is attracted towards the negative plates and thus deflected towards the right

β is (–) charged, it is attracted towards the positive plate and thus deflected towards the left

Since β is lighter than α, thus the deflection of β is greater.

24. D

✓ A. α-particles have a very low penetrating power in matter, they are stopped by a piece of paper.

✓ B. α-particles are radiation that can blacken films.

✓ C. α-particles have a very short range in air, about several centimeters.

× D. α are particles, they can travel in vacuum.

25. C

✓ (1) α-source emits α-particles that can ionize air molecules to give ion-pairs.
The ion-pairs can discharge sphere.

✓ (2) Touching the sphere with a finger is an Earthing process that can discharge the sphere.

× (3) Since the rod does not touch the sphere,
there is no flow of charge and does the charge in the sphere remains the same

26. D

Corrected count rate initially = 560 − 80 = 480 counts per minute

Corrected count rate after 6 hours = 140 − 80 = 60 counts per minute

Change of corrected count rate after each half-life : 480 ⟶ 240 ⟶ 120 ⟶ 60

∴ Half-life = $\frac{6}{3}$ = 2 hours

27. D

× A. α : not a wave

× B. γ : do not have charge ⇒ cannot be deflected by *B*-field

× C. γ : weak ionization power

✓ D. α : particles can travel in vacuum ; γ : electromagnetic waves can also travel in vacuum.

28. D

Radioactive sources should be stored in **lead** castles but not a wooden box only since lead is the most effective material to stop the radiations

29. D

Activity : 2000 ⟶ 1000 ⟶ 500 ⟶ 250 ⟶ 125

Number of half-lives = 4

Half-life = 4 hours × $\frac{1}{4}$ = 1 hour = 60 minutes

30. C

Neutrons are neutral particles. They would not be deflected by magnetic field or electric field.

31. B

× (1) α particles carry positive charges, they can be deflected by a magnetic field.
γ rays are neutral, they cannot be deflected by a magnetic field.

✓ (2) The ionizing power in descending order is α > β > γ

× (3) The speed of α particles is less than the speed of light in air but γ rays have the same speed as light in air

32. C

The half-life of *P* is 10 minutes.

The half-life of *Q* is 5 minutes, thus after 10 minutes, the activity of *Q* drops to one quarter.

Ratio of the half-life of *P* to that of *Q* = 10 : 5 = 2 : 1

33. C

After inserting the paper, the count rate is approximately unchanged, thus the source does not emit α.

After inserting the 5 mm Al, the count rate drops significantly, thus the source emits β.

After inserting the lead, the count rate drops significantly, thus the source emits γ.

34. B

P detects γ radiation since γ does not deflect in magnetic field

Q detects β radiation since magnetic force acts downwards on negative charged particles by using Left hand rule.

35. C

$X: N \xrightarrow{\text{2 days}} \frac{1}{2}N \xrightarrow{\text{2 days}} \frac{1}{4}N \xrightarrow{\text{2 days}} \frac{1}{8}N$

$Y: 8N \xrightarrow{\text{1 days}} 4N \xrightarrow{\text{1 days}} 2N \xrightarrow{\text{1 days}} N \xrightarrow{\text{1 days}} \frac{1}{2}N \xrightarrow{\text{1 days}} \frac{1}{4}N \xrightarrow{\text{1 days}} \frac{1}{8}N$

After 6 days, both *X* and *Y* have the same number of undecayed atoms of $\frac{1}{8}N$

36. A

From the graph, the background radiation is 50.

The initial total count rate is 350, thus the initial corrected count rate is 350 − 50 = 300.

After one half-life, the corrected count rate should drop to 150, thus the total count rate is 150 + 50 = 200.

The total count rate drops to 200 after 4 minutes, thus the half-life is 4 minutes.

37. C

Lead is the suitable metal to be used in the container since most radiation can be blocked by lead.

The symbol represents RADIOACTIVE substance.

38. D

× A. Time for all the radioactive nuclei to decay is infinite, half of this time is also infinite.

× B. Time for a radioactive nucleus to decay is random.

× C. Mass of the sample remains unchanged since the sample includes the mother nuclei and daughter nuclei..

✓ D. Time for half of the radioactive nuclei to decay is the definition of half-life.

39. D

× A. The person still receives the background radiation only, no extra radiation is received.

× B. Food that has been sterilized by exposure to gamma radiation does not have radiation remain.

× C. Listening to radio does not receive any radiation.

✓ D. Passengers in high-flying aeroplane receive greater amount of cosmic radiation.

40. B

× A. *β* particles carry negative charge since they are electrons.

✓ B. *β* particles can be deflected by a magnetic field, direction of deflection is found by Left hand rule.

× C. *β* particles can be deflected by an electric field, towards the positive plate.

× D. *β* particles can penetrate through sheets of paper, they can be stopped by aluminium.

41. D

Assume that the background count rate is *b* counts per minute.

After one half-life, the corrected count rate is reduced to half.

∴ $(1000 - b) \times \frac{1}{2} = (528 - b)$ ∴ $b = 56$

42. D

By Left hand rule, the magnetic force is pointing downwards.
In order to balance the magnetic force, the electric force should be pointing upwards.
Since the electric force is opposite to the electric field for a negative charge, the β particle,
thus the electric field is pointing downwards.

43. C

After a period of time, both the balls P and Q are discharged by the ions produced by the α particles.
Thus, the two neutral balls would not exert forces on each other.

44. B

① $(240) = (960)\left(\frac{1}{2}\right)^{2/t_{1/2}}$ $\therefore\ t_{1/2} = 1$ min.

② $(30) = (240)\left(\frac{1}{2}\right)^{t/1}$ $\therefore\ t = 3$ min.

OR

① $(240) = (960)\,e^{-k(2)}$ $\therefore\ k = 0.693\ \text{min}^{-1}$

② $(30) = (240)\,e^{-0.693\,t}$ $\therefore\ t = 3$ min

45. A

At P, the radiation is β since it is attracted upwards towards the positive side of the electric field.
At Q, the radiation is γ since it is not deflected by the electric field.
After applying the magnetic field, the magnetic force acting on β is upwards, thus the count rate at P decreases.
As the radiation at Q is γ which is not affected by magnetic field, the count rate at Q is the same.

46. A

× A. All the three types of nuclear radiations can travel through a vacuum.
✓ B. α radiation can be stopped by a piece of paper, and also by a thicker piece of aluminium.
✓ C. β particles are electrons moving with high speed.
✓ D. All the three types of nuclear radiations, including γ, can blacken a photographic film.

47. D

Initial corrected count rate = 1050 − 50 = 1000 counts per minute
Number of half-life period = 8 / 4 = 2
Corrected count rate after 8 hours = $1000 \times \left(\frac{1}{2}\right)^2$ = 250 counts per minute
Count rate after 8 hours = 250 + 50 = 300 counts per minute

48. C

By $A = kN$ $\therefore\ A \propto N$, activity is directly proportional to the number of undecayed nuclei.
The graph is a straight line passing through the origin.

49. D

After colliding with a helium nucleus, it must be a right-angled fork track.
Option B is not correct since the angle of separation is not 90°.

50. B

$$k = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{(72)} = 9.6\times10^{-3}\ \text{s}^{-1}$$

51. C

As the alpha particles would ionize the air, the ions then discharge the gold-leaf,
thus the gold-leaf would collapse.

52. D

At the end of 2 years, there is 2% Polonium remaining, thus
$(2\%) = (100\%)\,e^{-k(2)}$ $\therefore\ k = 1.96\ \text{year}^{-1}$
At the end of 1 year : $N = N_o\,e^{-(1.96)(1)} = 0.14\,N_o$
$\therefore$ There is 14% of Polonium and 86% of Lead.

53. A

Presence of paper : shows a significant drop in counts per minute ⇒ the source emits α-rays
Presence of Al : shows a slight change in counts per minute ⇒ the source does not emit β-rays
Presence of Pb block : shows a significant drop in counts per minute ⇒ the source emits γ-rays

54. D

Let x be the initial count rate of P, then $(600 - x)$ is the initial count rate of Q.

$$P:\ x \xrightarrow{1\text{ hour}} \frac{x}{2} \xrightarrow{1\text{ hour}} \frac{x}{4} \xrightarrow{1\text{ hour}} \frac{x}{8} \xrightarrow{1\text{ hour}} \frac{x}{16}$$

$$Q:\ (600 - x) \xrightarrow{2\text{ hours}} \frac{600 - x}{2} \xrightarrow{2\text{ hours}} \frac{600 - x}{4}$$

After 4 hours : $\frac{x}{16} + \frac{600 - x}{4} = 60$ $\therefore\ x = 480$ cpm

55. C

Let b be the background radiation.
After one half-life, the corrected count rate is reduced to half.
$(120 - b) \times \frac{1}{2} = (64 - b)$
$\therefore\ b = 8$
After inserting the lead sheet, all the α particles would be absorbed.
Thus, the detector can then only measure the background radiation, which is 8 counts per minute.

56. D

Let b be the background radiation.

$(100 - b) \times \frac{1}{2} = (80 - b)$ $\therefore$ $b = 60$ cpm

$\therefore$ Activity of the source at noon $= 100 - 60 = 40$ cpm

After 3 hours, activity : $40 \xrightarrow{1\text{ hour}} 20 \xrightarrow{1\text{ hour}} 10 \xrightarrow{1\text{ hour}} 5$

$\therefore$ Expected count rate $= 60 + 5 = 65$ cpm

57. C

When the activity drops to $\frac{1}{3}$ of its initial value : $\left(\frac{1}{3}A\right) = A \cdot e^{-k(12)}$ $\therefore$ $k = 0.0916\ \text{s}^{-1}$

When the activity drops to $\frac{1}{9}$ of its initial value : $\left(\frac{1}{9}A\right) = A \cdot e^{-(0.0916)(t+12)}$ $\therefore$ $t = 12$ s

58. A

Cardboard :	Due to the absorption of α-radiation, the count rate should drop.
1 mm of Al :	Since there is no β-radiation, the count rate should remain the same as x.
5 mm of Pb :	The count rate should drop due to the partial absorption of γ-radiation. However, the lead would not absorb all the γ-radiation, thus the count rate cannot drop to 50 cpm. Thus, the value of z should be 150.

59. D

× (1) Type of radiation cannot be known from the count rate at different times

✓ (2) Y has the shortest half-life since after 20 minutes it drops to about $\frac{1}{4}$

By decay constant $k = \dfrac{\ln 2}{t_{1/2}}$ $\therefore$ Y has the largest decay constant

✓ (3) Z has the longest half-life since after 20 minutes it drops only to about 70 %

60. B

By $A = A_o\, e^{-kt}$

① $(70) = A_o\, e^{-k(5)}$

② $(49) = A_o\, e^{-k(10)}$

$\therefore$ $\dfrac{70}{49} = e^{5k}$ $\therefore$ $k = 0.0713$ $\therefore$ $A_o = 100$ Bq

61. B

The decay constant k is the chance of decay per unit time.

$\therefore$ $k = 10^{-6}\ \text{s}^{-1}$

Half-life $= \dfrac{\ln 2}{k} = \dfrac{\ln 2}{10^{-6}} = 6.93 \times 10^5$ s $= 8$ days ≈ 1 week

62. C

Since the time of 1 day is much less than the half-life of 5.3 years, activity remains constant in 1 day.

$\Delta N = A\,\Delta t = (1.0 \times 10^6) \times (1 \times 24 \times 3600) = 8.6 \times 10^{10}$

OR

$k = \dfrac{\ln 2}{5.3 \times 365 \times 24 \times 3600} = 4.147 \times 10^{-9}\ \text{s}^{-1}$

By $A_o = k N_o$ $\therefore$ $(1.0 \times 10^6) = (4.147 \times 10^{-9})\, N_o$ $\therefore$ $N_o = 2.41138 \times 10^{14}$

By $N = N_o \cdot e^{-k \cdot t}$ $\therefore$ $N = (2.41138 \times 10^{14}) \cdot e^{-(4.147 \times 10^{-9}) \cdot (1 \times 24 \times 3600)} = 2.41052 \times 10^{14}$

$\Delta N = 2.41138 \times 10^{14} - 2.41052 \times 10^{14} = 8.6 \times 10^{10}$

63. C

By $A = kN$ $\therefore$ Activity A depends on

① decay constant k or half-life $t_{1/2}$

② number of undecayed nuclei N in the source

By $t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$, decay constant k is related to the half-life.

64. C

(1) Radiation dose of watching television for 4 hours every day $= 0.005$ mSv/hr $\times$ 4 hr $= 0.02$ mSv

(2) Radiation dose of flying in an aircraft $= 0.001$ mSv/hr $\times$ 10 h/month $\times$ 12 months $= 0.12$ mSv

(3) Radiation dose of X-ray check $= 0.020$ mSv $\times 2 = 0.04$ mSv

Ascending order of total radiation dose : (1), (3), (2)

65. C

Decay constant is the probability of decay per unit time,

it means the fraction of the active nuclei present that decay in one second.

66. D

For nuclide P : $64 \to 32 \to 16 \to 8 \to 4 \to 2 \to 1 \to \frac{1}{2} \to \frac{1}{4} \to \frac{1}{8}$: time taken $= 2 \times 9 = 18$ days

For nuclide Q : $8 \to 4 \to 2 \to 1 \to \frac{1}{2} \to \frac{1}{4} \to \frac{1}{8}$: time taken $= 3 \times 6 = 18$ days

OR

By $(64 \times 10^{12}) \times \left(\dfrac{1}{2}\right)^{t/2} = (8 \times 10^{12}) \times \left(\dfrac{1}{2}\right)^{t/3}$

$\therefore$ $8 \times \left(\dfrac{1}{2}\right)^{t/2} = \left(\dfrac{1}{2}\right)^{t/3}$

$\therefore$ $2^3 \times 2^{-t/2} = 2^{-t/3}$

$\therefore$ $3 - t/2 = -t/3$

$\therefore$ $t = 18$ days

67. B

✓ (1) By $k = \ln 2 / t_{1/2}$, X has shorter half-life, thus X has greater decay constant k.
By $A = kN$, X has greater decay constant k, thus the activity of X in sample P is higher.

× (2) After 8 hours, the number of X in P drops to 1/16 and the number of Y in Q drops to 1/4.
Thus the number of X in sample P is less.

✓ (3) The chance of decay in unit time is the decay constant.
As the decay constant of X is greater, the chance is also greater.

68. B

By $A = A_o e^{-kt}$

$\therefore$ $(54) = (250) e^{-k(30)}$

$\therefore$ $k = 0.0511 \text{ min}^{-1}$

At $t = 10$ min. : $A = (250) e^{-(0.0511)(10)} = 150$ Bq

69. D

(3) wavelength of ultra-violet radiation is of the order of 10^{-8} m

(2) grating spacing is of the order of 10^{-6} m

(1) range of α in air is of the order of 10^{-2} m (a few cm)

70. C

For X: 12 hours is two half-lives $\therefore$ $A_X = A_o \times (\frac{1}{2})^2 = \frac{1}{4} A_o$

After 12 hours,

$A_X : A_Y = 4 : 1$

$\therefore$ $A_Y = \frac{1}{4} A_X = \frac{1}{4} \times (\frac{1}{4} A_o) = \frac{1}{16} A_o$

For Y: $A = A_o (\frac{1}{2})^{t/t_{1/2}}$

$\therefore$ $(\frac{1}{16} A_o) = A_o (\frac{1}{2})^{(12)/t_{1/2}}$ $\therefore$ $t_{1/2} = 3$

$\therefore$ half-life of Y = 3 hours

71. D

× (1) The nature or type of radiation (α, β, γ) emitted would not affect or relate to the activity of the source.

✓ (2) The activity A is proportional to the decay constant k, which is related by the half-life.

✓ (3) The activity A is proportional to the number of active (undecayed) nuclei N.

72. C

After inserting the paper, the count rate is approximately unchanged, thus the source does not emit α.
After inserting the 5 mm Al, the count rate drops significantly, thus the source emits β.
After inserting the lead, the count rate drops significantly, thus the source emits γ.

73. B

× A. Since there is no count rate recorded at positions above X, the source may or may not emit α radiations.

✓ B. Since the count rate at Y is greater than X, there must be some radiation deflected downwards to reach Y.
By Left hand rule, the downward magnetic force should act on negative particles, that is, β radiations.

× C. The source may or may not emit γ radiation,
as the count rate at X may consist of γ and background or background only

× D. The source may emit γ radiation, thus the count rate of 101 cpm at X may be due to γ and background.

74. C

✓ (1) The mass of an α particle is the mass of a helium nucleus but the mass of a β particle is nearly zero.

× (2) The penetrating power of α is weaker than β.

✓ (3) α particles can ionize the air, the ions then discharge the charged metal sphere.

75. C

By $N = N_o (\frac{1}{2})^{10/20} = 0.707 N_o$

$\therefore$ $f = \frac{N}{N_o} = 0.707$

$\therefore$ $0.75 > f > 0.5$

76. C

Cathode rays (beam of electrons) is emitted from F which is the negative terminal, thus Q is the positive terminal.

When electrons hit the metal target at T, X-rays are emitted from T.

77. B

$M = M_o (\frac{1}{2})^{t/t_{1/2}}$

$= (420) (\frac{1}{2})^{70/140}$

$= 297$ mg

78. A

Note that γ radiation can never be totally absorbed.

Thus, z must be greater than the background radiation of 50 counts per minute.

The only option is A that z is 100 counts per minute.

79. A

α-radiation cannot pass through the plastic bag to reach the film, thus α-radiation cannot be detected by film badge.

The other 3 types of radiation can pass the plastic bag to reach the film inside the badge to be detected.

80. A

✓ (1) Ionizing power of ionizing radiation in descending order is $\alpha > \beta > \gamma >$ X-ray

× (2) γ-radiation can never be completely shielded by concrete wall, no matter how thick it is.

× (3) Only α and β will be deflected in an electric field as they carry charges.
γ radiation is an electromagnetic wave, it cannot be deflected in an electric field.

81. C

By $N = N_o (\frac{1}{2})^{t/t_{1/2}}$

$\therefore N_X (\frac{1}{2})^{24/3} = N_Y (\frac{1}{2})^{24/4}$

$\therefore N_X (\frac{1}{2})^{8} = N_Y (\frac{1}{2})^{6}$

$\therefore \frac{N_X}{N_Y} = \frac{4}{1}$

82. C

× A. Both β and γ can ionize air particles.

× B. Both β and γ can travel through vacuum.

✓ C. Both of them can be detected by a film.

× D. Only β carries charge, γ is neutral.

83. A

In an electric field, β that carries negative charge will deflect towards the (+) plate, thus it deflects upwards.

α that carries positive charge will deflect towards the (–) plate, thus it deflects downwards.

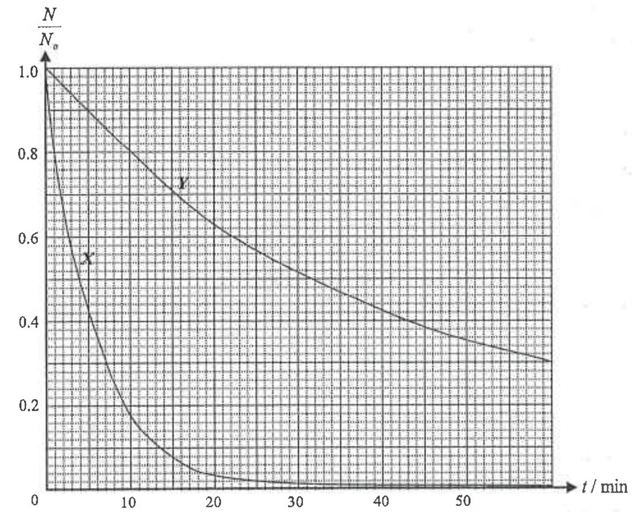
As mass of β is much smaller than that of α, the deflection of β should be much greater than that of α.

The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$

Part A : HKCE examination questions

1. **< HKCE 1982 Paper I - 8 >**



The above figure show the decay curves of two radioactive elements X and Y both emitting β-particles. N_o is the number of radioactive atoms present at time $t = 0$ and N is the number at the end of t minutes.

(a) What are the half-lives of X and Y ? (2 marks)

____

____

(b) A mixture of X and Y is placed in front of a Geiger counter. Initially, they have the same number of radioactive atoms. Which of the two, X or Y, will be mainly responsible for the reading shown on the Geiger counter during the first four minutes ? Estimate the fraction of the total number of counts due to that element. (5 marks)

____

____

____

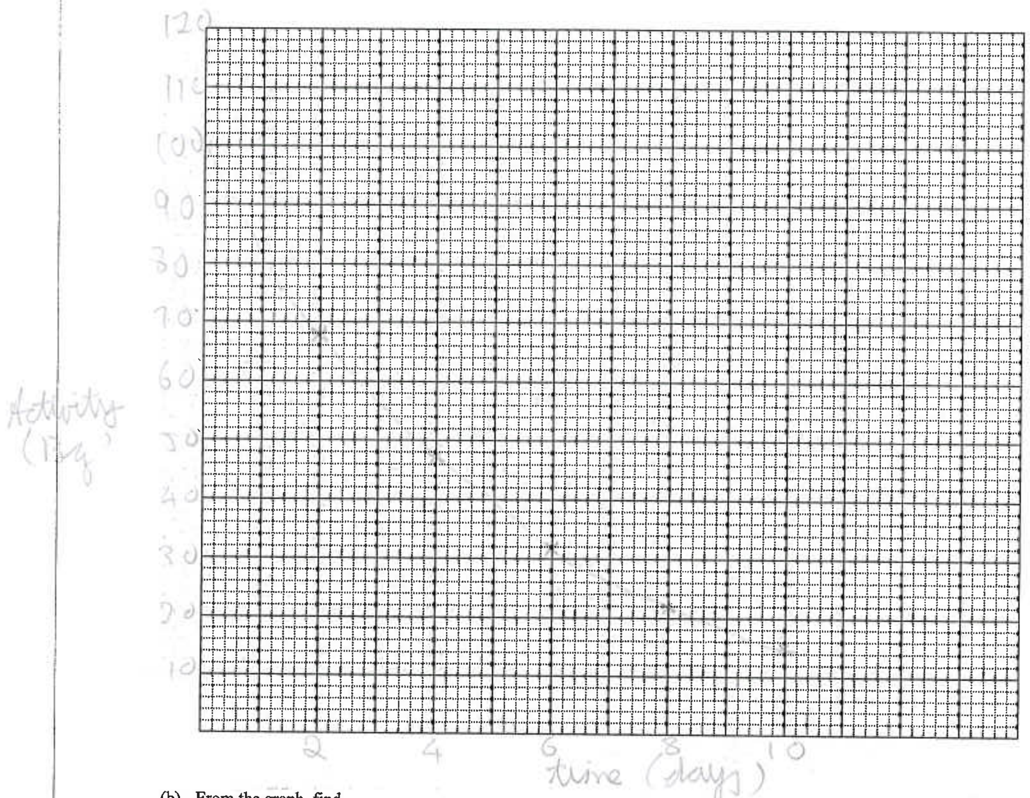
____

2. **< HKCE 1983 Paper I - 9 >**

The activity from a sample of Radium is measured at two-day intervals. The readings are tabulated below :

Time / days	0	2	4	6	8	10
Activity / Bq	100	68	47	32	22	15

(a) Plot the decay graph below to show the activity against time. (4 marks)



(b) From the graph, find (2 marks)

(i) the activity of the sample after 5 days, and

(ii) the half-life of the sample.

3. **< HKCE 1983 Paper I - 9 >**

A Geiger-Muller counter is placed on a bench.

(a) Explain why the counter registers a reading even when no radioactive source is placed nearby. (1 mark)

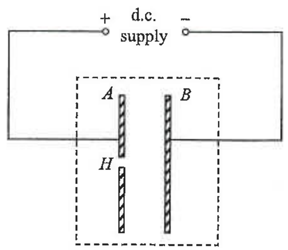
(b) When a radioactive source is placed near the counter, the counter registers 520, 510 and 514 counts per minute in the first three consecutive minutes. Explain why the three readings differ from each other ? (2 marks)

(c) When a piece of paper is placed between the source and the counter, the counter registers 540, 510 and 512 counts per minute in the first three consecutive minutes. However, when the paper is replaced by an aluminium sheet, the counter gives reading of 7, 9 and 8 counts per minute in three consecutive minutes.

What type(s) of radiation (α, β or γ) is/are being emitted by the source ? Give a reason for your answer. (4 marks)

4. **< HKCE 1984 Paper I - 9 >**

Two parallel metal plates *A* and *B* are placed in a vacuum chamber as shown in the figure below. They are connected to a d.c. supply. A hole *H* is drilled in plate *A*. A particle *P* passes through hole *H* and accelerates towards plate *B*.

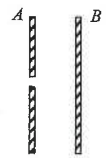


(a) What is the sign of the charge carried by *P* ? (1 mark)

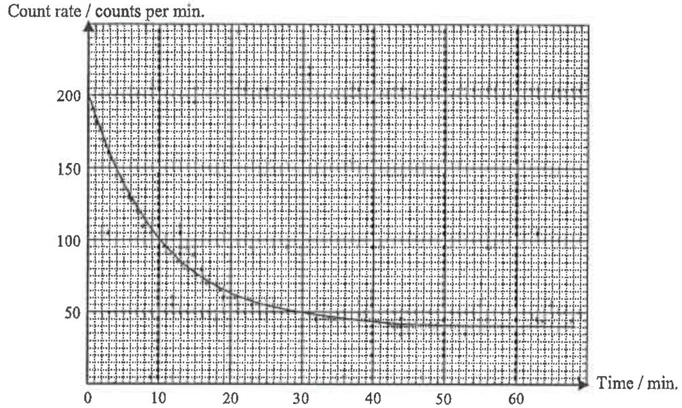
(b) The particle *P* is emitted from a radioactive source which undergoes α-, β- and γ-decay simultaneously.

(i) What kind of particle (α, β or γ) should *P* be ? (1 mark)

(ii) Draw a diagram to show how to prevent the other two kinds of particles from reaching *H*. Show the tracks of the particles in your diagram. (4 marks)



5. < HKCE 1986 Paper I - 9 >



The figure above shows the variation of count rate of a radioactive source measured by a GM counter with time.

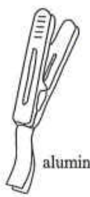
(a) Find from the figure, the background count rate of the room. (2 marks)

(b) Find the count rate due only to the radioactive source at time 0. (2 marks)

(c) Determine the half-life of the radioactive source. (2 marks)

6. < HKCE 1987 Paper I - 9 >

The below figure shows a pair of positively charged aluminium foils.



(a) When the aluminium foils are placed near an α source, the foils are found to gradually collapse. Briefly explain why. (2 marks)

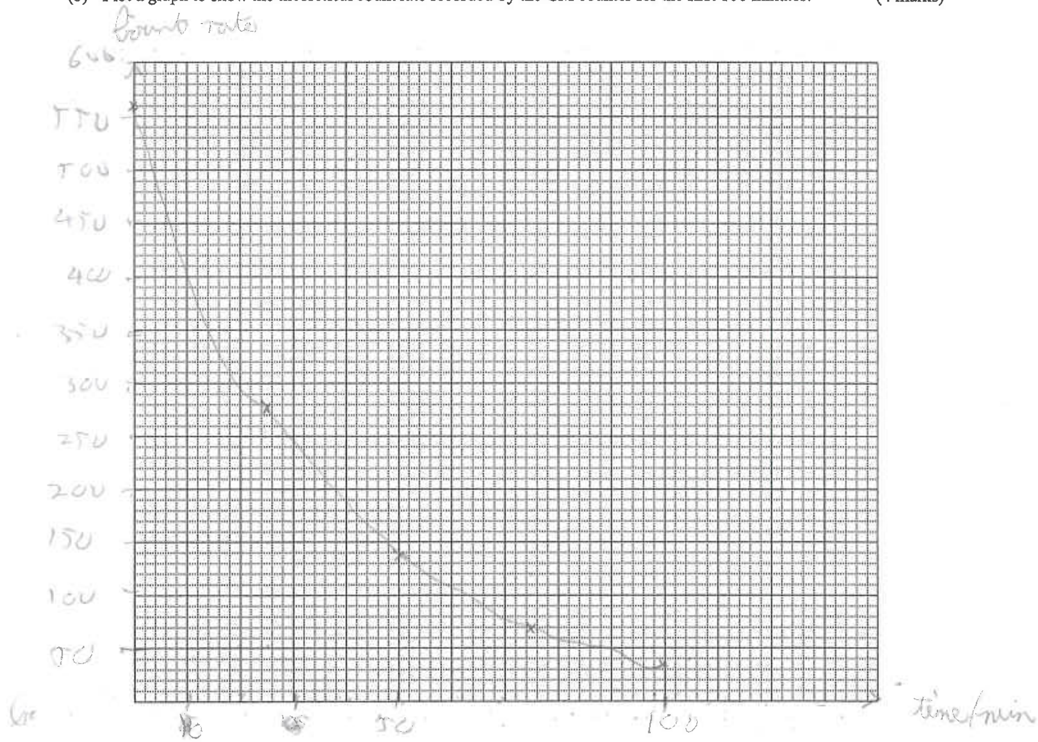
(b) Would the foils collapse faster or slower if the foils were placed near a γ source instead of an α source ? Explain briefly. (2 marks)

7. < HKCE 1989 Paper I - 9 >

A student measures the count rate of a source of half-life of 25 min using a GM counter in a room with very little background radiation. Initially the reading of the GM counter shows 560 counts per second.

(a) What should be the count rate of the source after 25 minutes ? (2 marks)

(b) Plot a graph to show the theoretical count rate recorded by the GM counter for the first 100 minutes. (4 marks)



(c) The actual readings of the GM counter are as follows:

Time / min.	0	50	75	100
Count rate / counts per second	560	154	70	31

Do you think that the GM counter is working properly ? Explain briefly. (3 marks)

8. **< HKCE 1989 Paper I - 9 >**

(a) What is the major source of background radiation

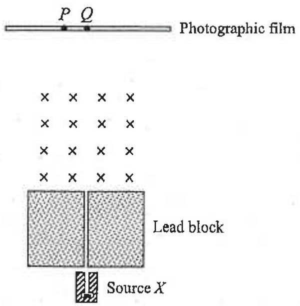
(i) at an altitude of 10000 m above sea-level ;

(ii) inside the Lion Rock Tunnel ;

(iii) in an underground coal mine ? (3 marks)

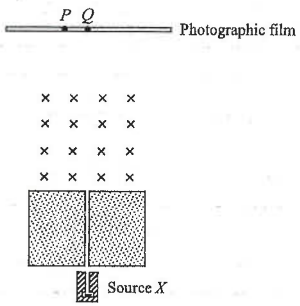
(b) It is reported that the background radiation in a concrete building is higher than that in a wooden hut. A person thus decides to move to a wooden hut. Do you think that his decision is wise ? Explain briefly. (3 marks)

9. **< HKCE 1990 Paper I - 9 >**



The above figure shows the set-up of an experiment carried out in an evacuated chamber to study the radiation from a radioactive source X. X emits α, β and γ radiation. A magnetic field (pointing into the paper) is applied. The photographic film is developed and marks in the positions P and Q are observed.

(a) In the figure below, sketch and label the paths of the α, β and γ radiation emitted from the source X. (5 marks)



9. (b) Explain briefly

(i) why the experiment is carried out in an evacuated chamber ; (2 marks)

(ii) the use of the lead block in the set-up. (2 marks)

(c) If a piece of cardboard is placed between the source and the lead block, what type(s) of radiation would be recorded on the photographic film ? (2 marks)

(d) Suggest an alternative detector to replace the photographic film in the experiment. (2 marks)

10. **< HKCE 1993 Paper I - 7 >**

A cloud chamber is used to observe the tracks of α-particles.

(a) Describe the tracks of α-particles in the cloud chamber. (2 marks)

(b) An α-particle collides with a helium nucleus to form a fork track. What is the angle of the fork track and what does this angle indicate ? (2 marks)

11. **< HKCE 1995 Paper I - 7 >**

In a school laboratory, the background count rate recorded by a GM counter is 100 counts per minute.

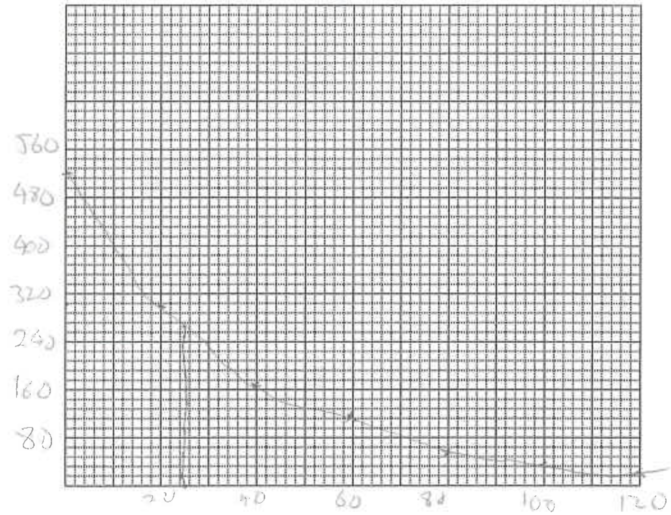
(a) The counter is placed close in front of a radioactive source *P*. The following results are obtained :

Time *t* / hour	0	20	40	60	80	100	120
Recorded count rate / counts per minute	620	400	270	199	157	133	118

520 300 170 99 57 33 18

(i) Find the corrected count rate at $t = 0$. (1 mark)

(ii) Plot the graph of the corrected count rate against time on the graph below. (5 marks)



(iii) Hence find the half-life of the source. (1 mark)

(b) To find out the kind(s) of radiation emitted by *P*, sheets of difference materials are placed in turn between *P* and the counter. The following results are obtained :

Material	Recorded count rate / counts per minute
–	620
Paper	623
5 mm Aluminium	98
5 mm Lead	101

Explain how the result shows that *P* emits β radiation only and it does not emit α or γ radiation. (3 marks)

11. (c) If the experiment in (b) is repeated with another source *Q* which emits both α and γ radiation, a different set of readings would be obtained, as shown in the below table.

Material	Recorded count rate / counts per minute
–	750
Paper	*x*
5 mm Aluminium	*y*
5 mm Lead	*z*

From the following list, choose suitable values for *x*, *y* and *z* :

0, 100, 195, 540, 750

(Note : A reading may be used more than once.) (3 marks)

12. **< HKCE 1999 Paper I - 6 >**

To investigate the kind(s) of radiation emitted by a radioactive source, a Geiger-Muller counter is placed close in front of the source and sheets of different absorbers are placed in turn between the source and the counter. Three readings are taken at one-minute intervals for each absorber. The following results are obtained :

Absorber	Recorded count rate / counts per minute		
	1st reading	2nd reading	3rd reading
–	700	710	693
Paper	702	703	701
1 mm Aluminium	313	320	317
5 mm Lead	98	101	100

The background count rate recorded by the counter is 100 counts per minute.

(a) Explain why the three readings for each absorber are not identical. (1 mark)

(b) Explain how the above results show that the source emits β radiation only and it does not emit α and γ radiation. (4 marks)

13. < HKCE 2001 Paper I - 11 >

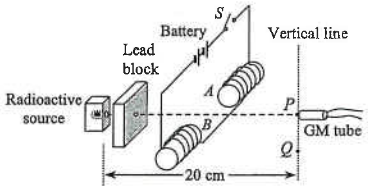


Figure 1

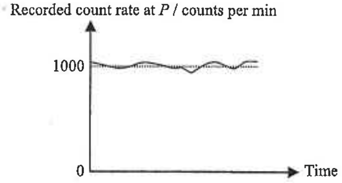


Figure 2

Figure 1 shows a set-up used to study the radiation from a radioactive source. A GM tube is placed at position P, which is at 20 cm from the source. Two coils A and B connected to a battery and a switch S are placed between the source and the GM tube as shown. Initially, S is open and the variation of the count rate recorded by the GM tube with time is shown in Figure 2.

(a) Explain why the count rate shown in Figure 2 is **not** due to α particles, no matter what kinds of radiation are emitted by the source. (2 marks)

(b) Now switch S is closed. The GM tube is placed at positions P and Q in turn (see Figure 1) and the count rates recorded are shown in Figure 3 and 4 respectively. When the GM tube is placed at any point vertically above P, an average count rate of 100 counts per minute is recorded at each point.

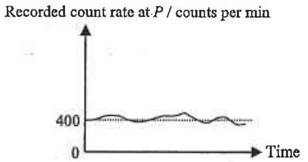


Figure 3

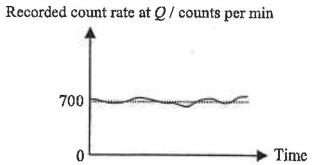


Figure 4

(i) State the direction of the magnetic field formed between coils A and B. (1 mark)

(ii) What kind of radiation is recorded when the GM tube is held at any point vertically above P ? Explain your answer. (3 marks)

(iii) What conclusion about the radiation emitted by the source can you draw from Figure 3 and Figure 4? Explain your answer. (4 marks)

(iv) Explain why the sum of the average count rates recorded in Figure 3 and Figure 4 is greater than that recorded in Figure 2. (2 marks)

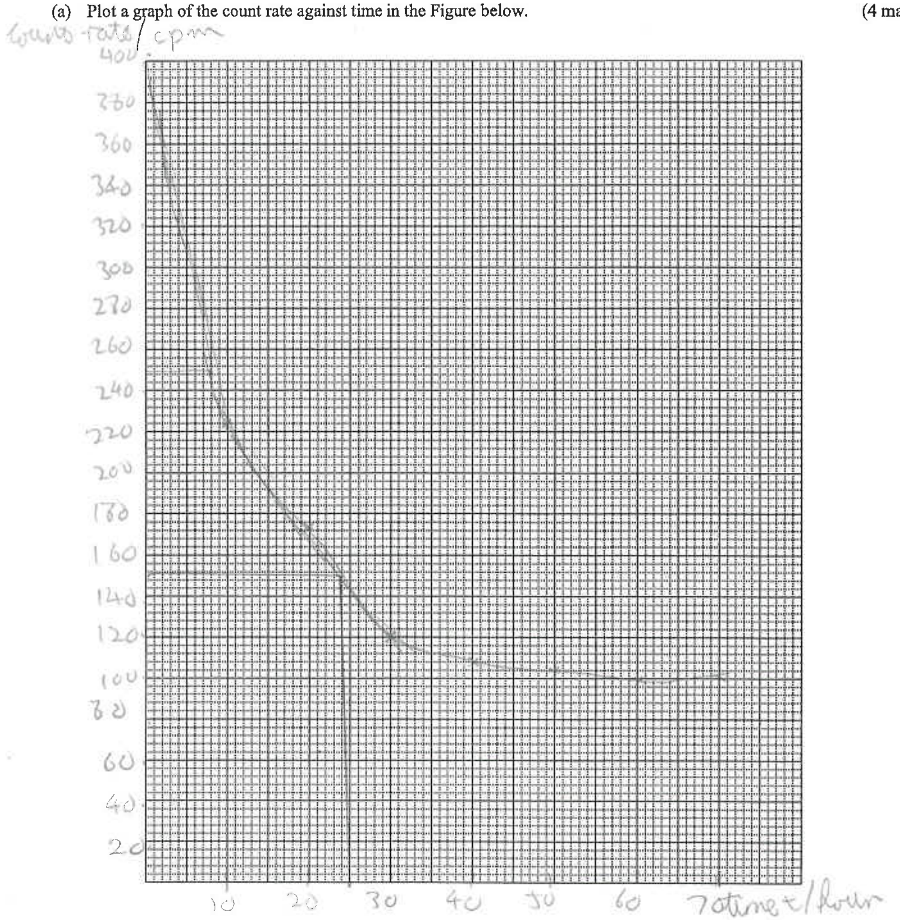
(c) The above experiment **cannot** determine whether α particles are emitted by the source. Suggest a method for finding out the answer. (2 marks)

14. < HKCE 2005 Paper I - 8 >

Carol performs an experiment to measure the half-life of a radioactive source. She places a Geiger-Muller tube in front of the source and the following results are obtained :

Time t / hour	0	10	20	30	40	50	60	70
Count rate / counts per minute	400	225	154	119	107	105	100	102

(a) Plot a graph of the count rate against time in the Figure below. (4 marks)



(b) Estimate the background count rate. (1 mark)

(c) Estimate the corrected count rate at $t = 0$. Hence, or otherwise, estimate the half-life of the source. (2 marks)

15. **< HKCE 2006 Paper I - 8 >**

Workers of nuclear plants are required to wear film badges (see Figure 1) to monitor their exposure to radiation. Inside the film badge, an opaque plastic bag is wrapped around a sheet of photographic film. Aluminium and lead sheets are also placed inside the badge (see Figure 2) so that the types of incoming radiation can be distinguished.

Figure 1

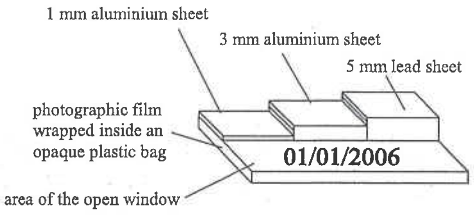


Figure 2

(a) What type(s) of radiation cannot be detected by the badge ? (1 mark)

(b) Why is an opaque plastic bag used to wrap the photographic film ? (1 mark)

(c) The films of three workers John, Mary and Ken were developed. The Table below shows the degrees of blackening on different regions of the films inside the badges which they wore.

Regions on the film	Degree of blackening (0 – 5) (0 = not blackened; 5 = most blackened)		
	John	Mary	Ken
Beneath the open window	5	5	5
Beneath the 1 mm aluminium sheet	5	3	4
Beneath the 3 mm aluminium sheet	5	1	2
Beneath the 5 mm lead sheet	4	0	0

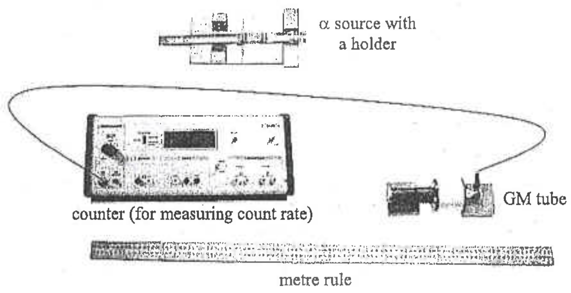
(i) Based on the results in the above Table, explain which type(s) of radiation John and Mary are definitely being exposed to respectively. (3 marks)

(ii) Give one reason why different degrees of blackening were recorded on the films of Mary and Ken. (1 mark)

(d) Suggest one hazard of exposure to ionizing radiations. (1 mark)

16. **< HKCE 2007 Paper I - 8 >**

In a physics lesson, a teacher uses the apparatus shown in Figure 13 to find the range of α particles in the air. Describe the procedures of the experiment. (4 marks)

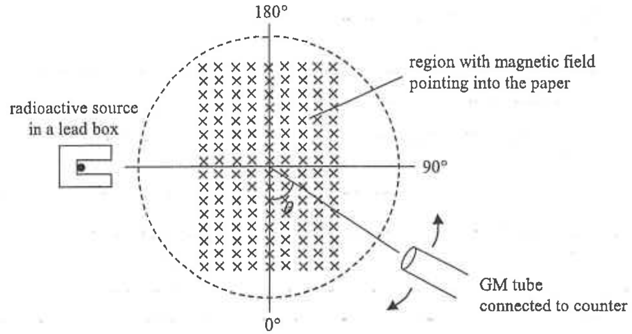


17. **< HKCE 2008 Paper I - 12 >**

(a) A teacher places a radioactive source 1 cm in front of a Geiger-Muller tube (GM tube) and measures the count rate. When he inserts a piece of paper between the radioactive source and the GM tube, he finds that there is no significant change in the measured count rate. State the conclusion about the type of radiation emitted from the radioactive source. (1 mark)

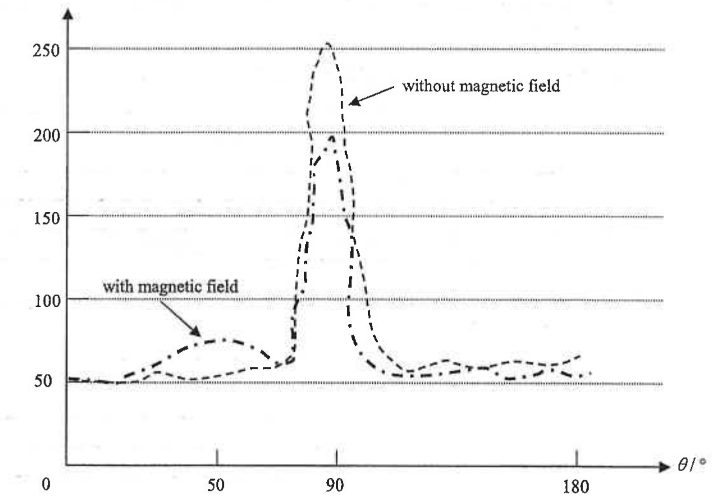
The teacher then conducts another experiment to investigate the deflection of radiations inside a magnetic field as shown in Figure 1. The GM tube can be rotated from 0° to 180° around the magnetic field. Figure 2 shows the count rate recorded at different angles with or without the magnetic field.

Figure 1



17.

Figure 2



(b) Estimate the count rate due to the background radiation. (1 mark)

(c) Using the result in Figure 2, explain why it can be concluded that the radioactive source emits β and γ rays. (4 marks)

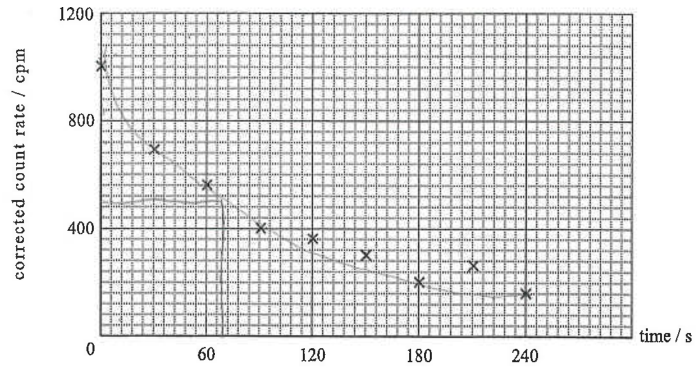
(d) Estimate the count rate due to each type of radiation at θ = 90° without the magnetic field. Write the answer in the Table below.

Type of radiation	Count rate / counts per minute
α	0
β	
γ	

(2 marks)

Part B : HKAL examination questions

18. < HKAL 1983 Paper IIB - 6 >



A radioactive source emits β particles. The corrected count rates are recorded and plotted in the above figure.

(a) A student comments that the readings have been taken carelessly because the points plotted in the above Figure do not fall on a smooth curve. Do you agree ? Explain your reasoning. (1 mark)

(b) Use the above Figure to estimate the half life of the radioactive source. (1 mark)

(c) Estimate the decay constant of protactinium-234. (1 mark)

(d) Express in words the relationship between the decay constant and the probability of an atom decaying. (1 mark)

Part C : HKDSE examination questions

19. **< HKDSE Practice Paper IB - 11 >**

The decay of radioactive isotope protactinium-238 (^{238}Pa) has a half-life of approximately 136 s. A sample of ^{238}Pa is put in front of a GM tube and the initial count rate is 1000 counts per minute. The background count rate is 50 counts per minute.

(a) It is known that the decay of ^{238}Pa does not emit γ radiation. Suggest a simple test to verify the radiation from ^{238}Pa is β radiation but not α radiation. (3 marks)

(b) Estimate the decay constant of ^{238}Pa. (1 mark)

(c) Hence, or otherwise, estimate the time taken for the count rate to drop to 250 counts per minute. (3 marks)

20. **< HKDSE 2014 Paper IB - 10 >**

Voyager I is a space probe designed by NASA to operate for over ten years in space. It was equipped with a radioisotope thermoelectric generator (RTG) which can convert the energy released from the decay of a radioactive source into electrical power. *Voyage I* operates with a plutonium-238 radioactive source that undergoes α-decay.

(a) The plutonium-238 source is sealed inside a thin metallic casing of the RTG. The photo shows a NASA staff handling the RTG with his bare hands. Explain why it is fine for it to be handled by the staff in this way. (1 mark)

20. When *Voyager I* was launched, the number of plutonium-238 atoms in the source was 3.2×10^{25}.

Given : half-life of plutonium-238 = 87.74 years.

Take 1 year = 3.16×10^{7} s.

(b) (i) Find the activity, in Bq, of the plutonium source at the time of launch. (3 marks)

(ii) When a plutonium-238 atom decays, it releases 5.5 MeV of energy. Estimate the power, in kW, delivered by the source at the time of launch. (2 marks)

(iii) The RTG of *Voyage I* is still in operation as *Voyage I* just left the solar system in September 2013 after it was launched 36 years ago. Estimate the corresponding power delivered by the plutonium source, expressed in percentage of the power delivered at the time of launch. (2 marks)

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

Question Solution

1. (a) Half-life of X = 4 min [1]

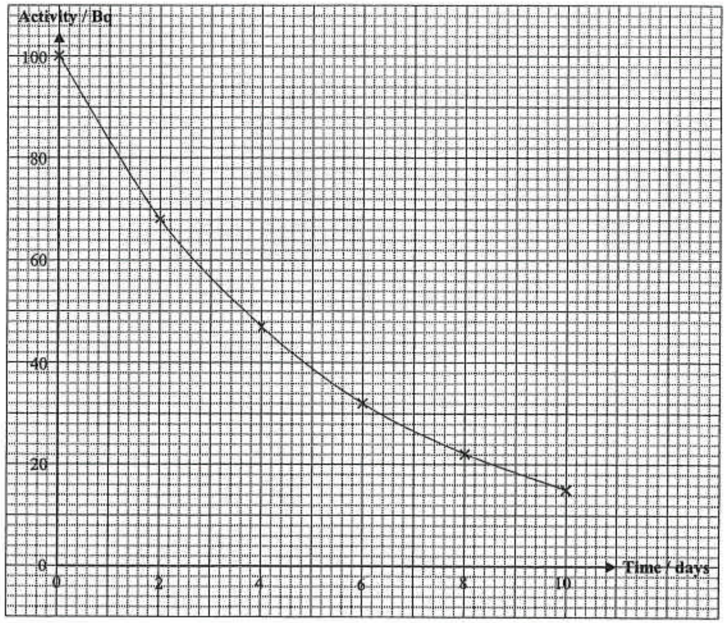
Half-life of Y = 32 min [1]

(b) X will be mainly be responsible for the reading [1]

Ratio of the number of counts due to X to that of Y = 0.5 : 0.08 [2]

Fraction of total number of counts due to X = $\frac{0.5}{0.5+0.08}$ = 0.862 [2]

2. (a)



< Two axes correctly labeled > [1]

< Scales properly marked > [1]

< Points correctly plotted > [1]

< Curve correctly drawn > [1]

(b) (i) activity after 5 days = 39 Bq < accept 38 Bq to 40 Bq > [1]

(ii) half-life = 3.7 days < accept 3.6 to 3.8 days > [1]

3. (a) There is background radiation. [1]

(b) It is due to the random nature of radiation. [2]

(c) β radiation only [1]

There is no α since α is stopped by paper. [1]

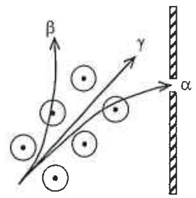
β is present since β is absorbed by aluminium and the count rate is reduced. [1]

There is no γ since the count rate left is very small which should be due to background radiation. [1]

4. (a) The charge is positive. [1]

(b) (i) α particle [1]

(ii) Use magnetic field [1]



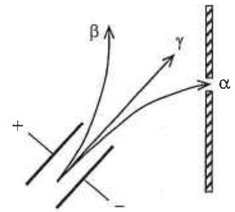
< correct deflection of α to the slit > [1]

< correct indication of the direction of the magnetic field > [1]

< β and γ correctly deflected > [1]

OR

Use electric field [1]



< correct deflection of α to the slit > [1]

< correct indication of the direction of the electric field or polarity > [1]

< β and γ correctly deflected > [1]

5. (a) Background count rate = 40 counts per minute [2]

(b) Count rate at time 0 = 200 – 40 [1]

= 160 counts per minute [1]

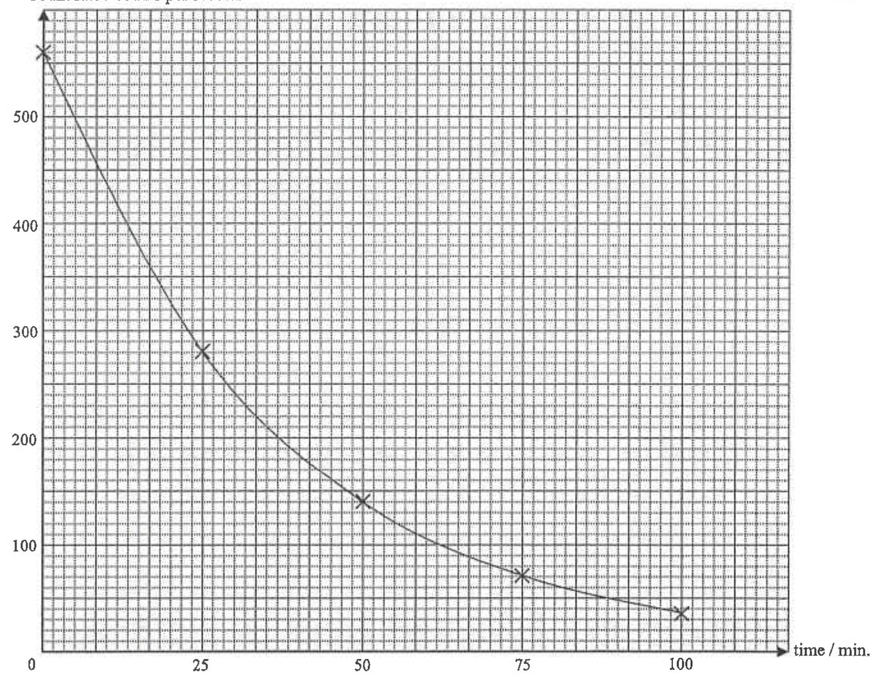
(c) Half-life = 7 minutes < accept 6.5 minutes to 7.5 minutes > [2]

6. (a) The α particles ionize air. [1]
The ions then discharge the aluminium foils. [1]

(b) The foils would collapse slower [1]
since γ has weaker ionizing power [1]

7. (a) 280 counts per second [2]

(b) [4]



(c) Yes, the GM counter is working properly. [1]
The readings do not match the theoretical curve exactly due to the random nature of radiation. [2]

8. (a) (i) cosmic radiation from the outer space [1]
(ii) from the rock [1]
(iii) from the coal (or carbon) [1]

8. (b) Both Yes or No are acceptable but the reasons should be consistent. [1]

Reason for Yes : [2]

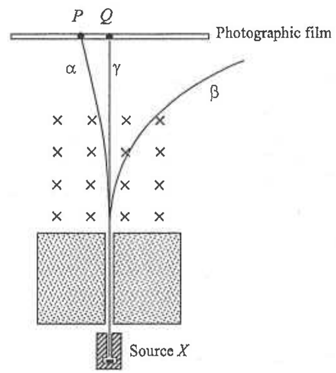
* The cumulative effect of radiation is harmful

Reason for No : (any **ONE**) [2]

* The background radiation in a concrete building is weak and not hazardous
* The chance of being harmed by other factors such as fire in a wooden hut is increased

< No mark is awarded if only answer Yes or No >

9. (a)



< 2 rays reaching P, Q > [1]
< α radiation – towards the left > [1]
< γ radiation – no deflection > [1]
< β radiation – towards the right > [1]
< β radiation not reaching the film > [1]

(b) (i) α-particles have short range in air. [2]
(ii) To produce a fine beam of radiation [2]

(c) γ radiation only [2]

(d) GM tube [2]

10. (a) The tracks are (ANY TWO) : [2]

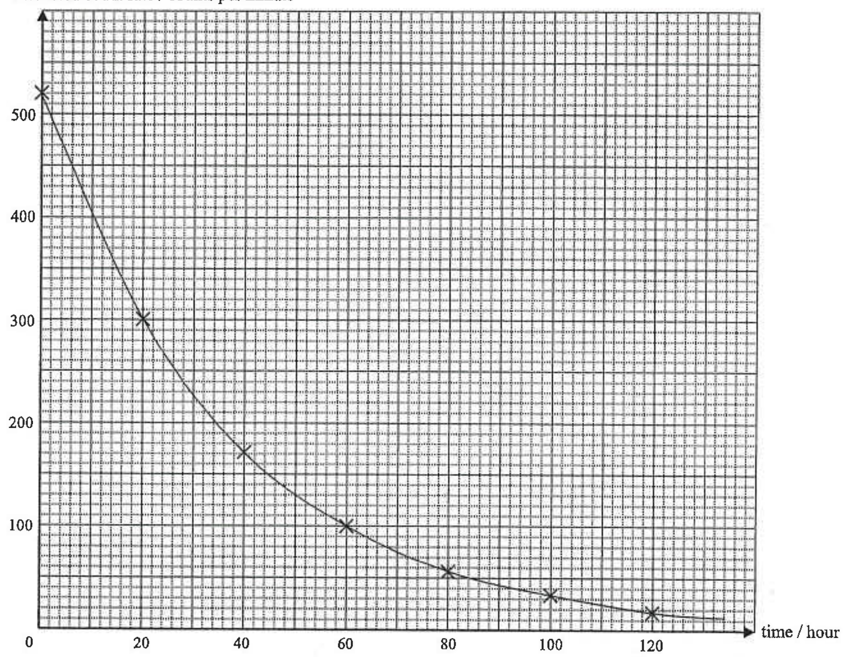
* straight
* thick
* short
* of about the same length

(b) The angle is 90° [1]
The masses of an α particle and a helium nucleus are the same. [1]

11. (a) (i) Corrected count rate = 520 counts per minute [1]

(ii) [1]

Time t / hour	0	20	40	60	80	100	120
Corrected count rate / counts per minute	520	300	170	99	57	33	18



< Correct label of the two axes with units > [1]

< An appropriate scale (not less than 1 cm to 50 c.p.m. and 1 cm to 10 hours) > [1]

< Correct points plotted > [1]

< Smooth curve drawn > [1]

(iii) From the graph, half-life = 25 hours < from 23 to 27 hours is acceptable > [1]

(b) The source does not emit α radiation
since the recorded count rate almost remains unchanged when a sheet of paper is inserted. [1]

The count rate drops significantly when aluminium is inserted, this illustrates that it emits β radiation. [1]

The source does not emit γ radiation
because the count rate is approximately unchanged when 5 mm lead is inserted. [1]

11. (b) **OR**

The source does not emit α radiation
since the recorded count rate almost remains unchanged when a sheet of paper is inserted. [1]

The count rate drops significantly when aluminium is inserted, this illustrates that it emits β radiation. [1]

The source does not emit γ radiation
because the count rate already drops to background rate when aluminium is inserted. [1]

(c) $x = 540$ [1]

$y = 540$ [1]

$z = 195$ [1]

12. (a) This is due to the random nature of radiation. [1]

(b) As the count rates remain unchanged when a sheet of paper is inserted,
the source does not emit α radiation. [1]

As the count rates drop significantly when 1 mm aluminium sheet is inserted,
the source emits β radiation. [1]

As the count rates drop to background radiation when 5 mm lead is inserted,
the source does not emit γ radiation. [1]

13. (a) The range of α particles in air [1]
is only a few centimeters. [1]

(b) (i) The magnetic field is directed from B to A. [1]

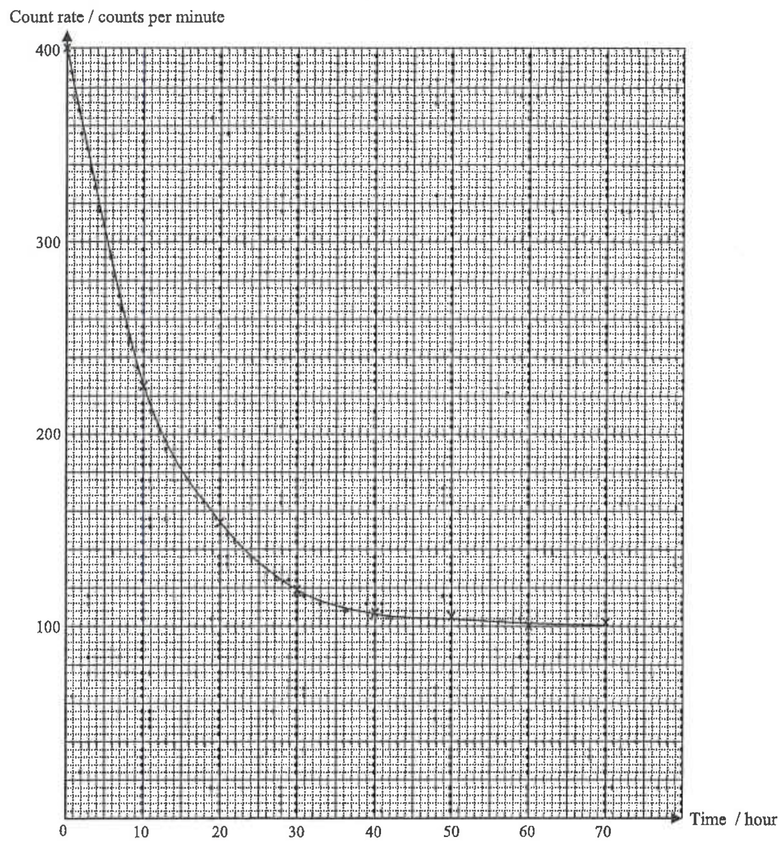
(ii) The count rate is due to background radiation only. [1]
β or γ cannot be deflected upward. [2]

(iii) As the count rate at P and Q are greater than the background radiation, some radiations are detected. [1]
As the radiation detected at P is not deflected by the magnetic field, it must be γ radiation. [1]
As the radiation detected at Q is deflected downwards by the magnetic field, it must be β radiation. [1]
So the source emits β and γ radiation. [1]

(iv) The background radiation is recorded at both Figure 3 and Figure 4, [1]
so the background radiation is counted twice and thus the sum is greater. [1]

(c) Place the GM tube close in front of the source. [1]
Insert a piece of paper in between.
If the count rate drops significantly, α particles are emitted. [1]

14. (a)



< Two axes correctly labelled with units > [1]

< An appropriate scale > [1]

< Correct points (at least 7 points correct) > [1]

< A curve through the points > [1]

(b) The background count rate is 100 counts per minute. < from 95 to 105 is acceptable > [1]

(c) The corrected count rate at $t = 0$ is 300 counts per minute. < from 295 to 305 is acceptable > [1]

The half-life is 8 hours. < from 7 to 9 hours is acceptable > [1]

15. (a) α radiation cannot be detected. [1]

(b) To prevent light rays from entering the bag and blackening the film. [1]

15. (c) (i) John is exposed to γ radiation [1]

since γ can pass through the 5 mm lead sheet and blacken the film. [1]

Mary is exposed to β radiation since the film under the aluminium sheets is blackened but the film under the 5 mm lead sheet is not blackened. [1]

(ii) The radiation dose received by Ken is higher than that of Mary. [1]

(d) Any **ONE** of the following : [1]

* It can destroy living cells.
* It can cause cancer.
* It can cause the genetic change.

16. Place the α source close to and facing the GM tube. [1]

Increase their separation gradually and observe the count rate reading. [1]

Mark the point for the rapid drop in count rate. [1]

Measure the distance between α source and the GM tube with the metre rule to give the range. [1]

17. (a) No α radiation from the source. [1]

(b) 50 counts per minute (50 cpm) < accept 50 to 60 cpm > [1]

(c) With magnetic field, a peak of count rate appears at 50°. [1]

As β-particles are negatively charged, they deflect inside the magnetic field. [1]

With magnetic field, a peak of current still exists at 90°. [1]

As γ-ray does not have charge, it does not deflect inside the magnetic field. [1]

(d) β : 50 < accept 50 to 60 > [1]

γ : 150 < accept 140 to 160 > [1]

18. (a) No! It is due to the random nature of radiation. [1]

(b) Half life = 72 s < from 60 to 84 s is acceptable > [1]

(c) $k = \dfrac{\ln 2}{72} = 0.00963\ s^{-1}$ < from $0.00825\ s^{-1}$ to $0.0116\ s^{-1}$ are acceptable > [1]

(d) The decay constant is equal to the probability of decay of an atom per unit time. [1]

OR

The decay constant is equal to the probability of decay of an atom in 1 s. [1]

19. (a) Insert a piece of paper between the sample and the GM tube.

The count rate will remain approximately unchanged, showing that no α radiation is emitted. [1]

Insert a 5 mm aluminium plate between the sample and the GM tube. [1]

The count rate will drop to the background count rate level, showing that β radiation is emitted. [1]

(b) $k = \dfrac{\ln 2}{136} = 5.10 \times 10^{-3}\ \text{s}^{-1}$ [1]

(c) Initial corrected count rate = 1000 – 50 = 950 cpm

Final corrected count rate = 250 – 50 = 200 cpm [1]

By $C = C_0 e^{-kt}$ **OR** By $C = C_0 \left(\dfrac{1}{2}\right)^{t/t_{1/2}}$ [1]

$\therefore\ (200) = (950)\, e^{-5.10\times10^{-3}\, t}$ $\qquad$ $\therefore\ (200) = (950) \left(\dfrac{1}{2}\right)^{t/136}$

$\therefore\ t = 306\ \text{s}$ $\qquad$ $\therefore\ t = 306\ \text{s}$ [1]

20. (a) The penetrating power of α is so weak that it cannot pass through the thin metallic casing of the RTG. [1]

(b) (i) $k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{(87.74 \times 3.16 \times 10^7)} = 2.50 \times 10^{-10}\ \text{s}^{-1}$ [1]

$A_o = kN = (2.50 \times 10^{-10})\,(3.2 \times 10^{25})$ [1]

$= 8.00 \times 10^{15}\ \text{Bq}$ [1]

(ii) $P = EA$

$= (5.5 \times 10^6 \times 1.6 \times 10^{-19})\,(8 \times 10^{15})$ [1]

$= 7040\ \text{W} = 7.04\ \text{kW}$ [1]

(iii) By $P = EA$ $\quad \therefore\ P \propto A$

$$\frac{P}{P_o} = \frac{A}{A_o} = e^{-(2.50\times10^{-10})\times(36\times3.16\times10^7)} \times 100\% = 75.2\%$$ [2]

OR

$$\frac{P}{P_o} = \frac{A}{A_o} = \left(\frac{1}{2}\right)^{t/t_{1/2}} = \left(\frac{1}{2}\right)^{36/87.74} \times 100\% = 75.2\%$$ [2]

< accept using the ratio of number of nuclei N > < accept 75% >

Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)
1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普通氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)
1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)
1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)
1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)
1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Physics – Elective part (選修部分)

Elective 1 – Astronomy and Space Science (天文學和航天科學)
1. The universe seen in different scales (不同空間標度下的宇宙面貌)
2. Astronomy through history (天文學的發展史)
3. Orbital motions under gravity (重力下的軌道運動)
4. Stars and the universe (恆星和宇宙)

Elective 2 – Atomic World (原子世界)
1. Rutherford's atomic model (盧瑟福原子模型)
2. Photoelectric effect (光電效應)
3. Bohr's atomic model of hydrogen (玻爾的氫原子模型)
4. Particles or waves (粒子或波)
5. Probing into nano scale (窺探納米世界)

Elective 3 – Energy and Use of Energy (能量和能源的使用)
1. Electricity at home (家居用電)
2. Energy efficiency in building (建築的能源效率)
3. Energy efficiency in transportation (運輸業的能源效率)
4. Non-renewable energy sources (不可再生能源)
5. Renewable energy sources (可再生能源)

Elective 4 – Medical Physics (醫學物理學)
1. Making sense of the eye (眼的感官)
2. Making sense of the ear (耳的感官)
3. Medical imaging using non-ionizing radiation (非電離輻射醫學影像學)
4. Medical imaging using ionizing radiation (電離輻射醫學影像學)

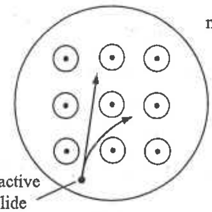
The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$

Part A : HKCE examination questions

1. **< HKCE 1980 Paper II - 40 >**

A radioactive nuclide ${}^{A}_{Z}X$ undergoes radioactive decay inside a cloud chamber. The radiations emitted are subjected to a magnetic field and the resulting tracks are as shown in the figure. What are the atomic number and the mass number of the remaining nuclide ?



	Atomic Number	Mass Number
A.	$Z-2$	$A-4$
B.	$Z+1$	$A-4$
C.	$Z+1$	A
D.	$Z-1$	$A-4$

2. **< HKCE 1980 Paper II - 39 >**

The two isotopes ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ of chlorine have different
(1) numbers of protons
(2) number of neutrons
(3) chemical properties

A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

3. **< HKCE 1981 Paper II - 31 >**

Which of the following statements concerning isotopes of an element is/are correct ?
(1) They have the same number of neutrons.
(2) They have the same chemical and physical properties.
(3) They have the same atomic number but different mass numbers.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

4. **< HKCE 1981 Paper II - 35 >**

Which of the following represents an alpha decay ?
(1) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th$
(2) ${}^{215}_{85}At \rightarrow {}^{211}_{83}Bi$
(3) ${}^{210}_{81}Tl \rightarrow {}^{210}_{82}Pb$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

5. < HKCE 1983 Paper II - 24 >

The atomic structure of isotopes of the same element differ from each other by having different numbers of
A. electrons.
B. neutrons.
C. electrons and protons.
D. electrons and neutrons.

6. < HKCE 1984 Paper II - 34 >

An ancient piece of wood was tested for its age by carbon-14 dating method. The normal emission rate from 2 g of carbon from a living plant is 20 counts per minute. If the rate from 2 g of carbon from the wood is 5 counts per minute, and the half life of carbon 14 is 5700 years, what is the approximate age of the wood in years ? (Background radiation may be neglected.)
A. 5700 × 4
B. 5700 × 2
C. 5700 / 2
D. 5700 / 4

7. < HKCE 1985 Paper II - 43 >

During radioactive decay, ${}^{230}_{90}X$ becomes ${}^{226}_{90}Y$. Which of the following statements would be correct ?
(1) The change would involve α decay only.
(2) One α particle and two β particles would be emitted.
(3) *X* and *Y* are two isotopes of the same element.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

8. < HKCE 1988 Paper II - 40 >

A U-235 nucleus would change to Ac-227 through a series of decay :

$${}^{235}_{92}U \xrightarrow{X} {}^{231}_{90}Th \xrightarrow{Y} {}^{231}_{91}Pa \xrightarrow{Z} {}^{227}_{89}Ac$$

What kind of particles are emitted at stages *X*, *Y* and *Z* in the radioactive decay chain shown above ?

	X	*Y*	*Z*
A.	α	α	β
B.	β	α	β
C.	β	β	α
D.	α	β	α

9. < HKCE 1988 Paper II - 38 >

The atomic number of Tin is 50 and its mass number is 112. Which of the following is an isotope of Tin ?
A. ${}^{112}_{51}X$
B. ${}^{114}_{50}X$
C. ${}^{112}_{49}X$
D. ${}^{112}_{62}X$

10. < HKCE 1989 Paper II - 39 >

${}^{235}_{92}U$ eventually decays to ${}^{207}_{82}Pb$. What is the number of α particles and β particles emitted during the decay ?

	α	β
A.	7	4
B.	7	10
C.	14	10
D.	28	4

11. < HKCE 1990 Paper II - 41 >

If the nucleus of an atom is represented by the symbol ${}^{214}_{83}X$, it means that this atom has
(1) 131 protons in its nucleus.
(2) 83 electrons outside its nucleus.
(3) 214 neutrons in its nucleus.
A. (1) only
B. (2) only
C. (3) only
D. (1) & (2) only

12. < HKCE 1992 Paper II - 39 >

${}^{238}_{92}U$ decays by emitting two α particles and two β particles. Which of the following represents the resulting nuclide ?
A. ${}^{234}_{90}Th$
B. ${}^{234}_{92}U$
C. ${}^{232}_{88}Ra$
D. ${}^{230}_{90}Th$

13. < HKCE 1994 Paper II - 39 >

Which of the following symbols represents a neutron ?
A. ${}^{0}_{0}n$
B. ${}^{1}_{0}n$
C. ${}^{0}_{1}n$
D. ${}^{1}_{1}n$

14. < HKCE 1995 Paper II - 40 >

A radioactive nuclide *W* decays to a nuclide *Z* by emitting one α-particle and two β-particles as shown below.

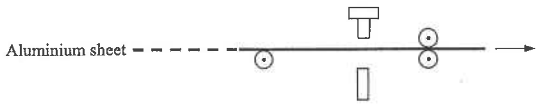
$$W \xrightarrow{\beta} X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$$

Which of the following statements about nuclides *W*, *X*, *Y* and *Z* is/are correct ?
(1) *W* and *Z* are isotopes.
(2) *X* has the greatest atomic number.
(3) *Y* has the greatest mass number.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

15. < HKCE 1997 Paper II - 40 >

Which of the following is **not** an application of radioactivity ?
A. Carbon-14 dating
B. Examination of foetuses (babies not yet born)
C. Killing cancer cells in human bodies
D. Sterilization of food

16. < HKCE 1998 Paper II - 41 >



In a factory producing aluminium sheets of 1 mm thickness, a thickness gauge is used to monitor the thickness of aluminium sheets. Which of the following states the correct radioactive source to be used in the thickness gauge and the reason behind ?

	Source	Reason
A.	α	The amount of α particles passing through aluminium depends on its thickness.
B.	β	The amount of β particles passing through aluminium depends on its thickness.
C.	β	β particles are less harmful to human beings.
D.	γ	γ radiation has the greatest penetrating power.

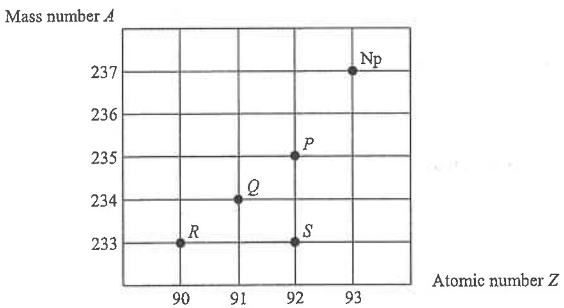
17. < HKCE 1998 Paper II - 39 >

A nucleus X emits a beta particle to form a daughter nucleus Y. Which of the following statements is/are correct ?

(1) X and Y have the same number of neutrons.
(2) The number of protons in X is greater than that in Y by 1.
(3) The total numbers of neutrons and protons in X and Y are equal.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

18. < HKCE 1999 Paper II - 39 >



The above diagram shows the mass number A and atomic number Z of a few nuclides. The isotope of neptunium (Np) shown decays by emitting an α particle and then a β particle.

Which of the following represents the resulting nuclide ?

A. P
B. Q
C. R
D. S

19. < HKCE 1999 Paper II - 40 >

Which of the following applications of radioactivity makes use of the fact that a radioactive nuclide has a constant half-life ?

A. Carbon-14 dating
B. Preservation of food
C. Smoke detectors
D. Thickness gauge

20. < HKCE 2001 Paper II - 41 >

The below shows part of a radioactive series.

$$P \xrightarrow{\alpha} Q \xrightarrow{\beta} R \xrightarrow{\beta} S$$

Which of the following nuclei are isotopes of the same element ?

A. P and Q
B. P and R
C. P and S
D. Q and S

21. < HKCE 2001 Paper II - 39 >

Radium $\left({}^{226}_{88}\text{Ra}\right)$ decays by emitting an α particle to form a product nucleus X. Which of the following shows the correct equation for this decay ?

A. ${}^{226}_{88}\text{Ra} + \alpha \longrightarrow {}^{230}_{90}\text{X}$
B. ${}^{226}_{88}\text{Ra} \longrightarrow {}^{224}_{84}\text{X} + \alpha$
C. ${}^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{X} + \alpha$
D. ${}^{226}_{88}\text{Ra} \longrightarrow {}^{226}_{89}\text{X} + \alpha$

22. < HKCE 2002 Paper II - 42 >

Which of the following is/are application(s) of radioactivity ?

(1) to estimate the age of ancient remains
(2) to kill bacteria in food
(3) to transmit signals over long distances

A. (2) only
B. (3) only
C. (1) & (2) only
D. (1) & (3) only

23. < HKCE 2002 Paper II - 40 >

A radioactive isotope ${}^{234}_{90}\text{Th}$ undergoes a series of decay processes to form a daughter ${}^{206}_{82}\text{Pb}$. How many α-particles and β-particles have been emitted in this decay process ?

	No. of α-particles	No. of β-particles
A.	6	7
B.	7	6
C.	7	8
D.	8	7

24. **< HKCE 2003 Paper II - 42 >**

Which of the following are essential criteria in choosing radioactive sources as medical tracers in human bodies ?
(1) The sources should have a short half-life.
(2) The radiation emitted should have a weak ionizing power.
(3) The radiation emitted should not be deflected by an electric field.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

25. **< HKCE 2004 Paper II - 42 >**

In order to detect cracks in an underground oil pipe, an engineer proposes adding a radioactive source to the oil. Which of the following sources is most suitable ?

A. a γ source with a half-life of a few hours
B. a γ source with a half-life of several years
C. an α source with a half-life of a few hours
D. an α source with a half-life of several years

26. **< HKCE 2005 Paper II - 25 >**

A thorium nucleus ($^{234}_{90}$Th) decays by emitting a β particle to form a daughter nucleus X. Which of the following equations represents this decay ?

A. $^{234}_{90}\text{Th} \longrightarrow {}^{230}_{88}X + \beta$
B. $^{234}_{90}\text{Th} \longrightarrow {}^{234}_{89}X + \beta$
C. $^{234}_{90}\text{Th} \longrightarrow {}^{233}_{90}X + \beta$
D. $^{234}_{90}\text{Th} \longrightarrow {}^{234}_{91}X + \beta$

27. **< HKCE 2006 Paper II - 43 >**

$$X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$$

$$P \xrightarrow{\beta} Q \xrightarrow{\beta} R \xrightarrow{\alpha} S$$

In the above two decay series, P and Y are two isotopes of the same element. Which of the following pairs of nuclides may be isotopes ?
(1) X and R
(2) Y and S
(3) Z and Q

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

28. **< HKCE 2006 Paper II - 27 >**

Some fresh foods are exposed to γ radiations from radioactive isotopes for a short time so that the micro-organisms in the foods can be killed. Why are the irradiated foods not harmful to people who eat them ?

A. γ radiation is an electromagnetic wave.
B. γ radiation has a high penetrating power.
C. γ radiation does not have a high ionizing power.
D. γ radiation does not make the foods radioactive.

29. **< HKCE 2007 Paper II - 25 >**

In the upper atmosphere, neutrons are produced by the action of cosmic rays. These neutrons interact with nitrogen nuclei as shown in the following reaction:

$$^{1}_{0}\text{n} + {}^{14}_{7}\text{N} \rightarrow X + {}^{1}_{1}\text{H}$$

Element X will then emit a β particle.
The nuclear reaction is as follows : $X \rightarrow Y + {}^{0}_{-1}\beta$.
What is the final product Y ?

A. $^{14}_{6}\text{C}$
B. $^{13}_{6}\text{C}$
C. $^{14}_{7}\text{N}$
D. $^{13}_{7}\text{N}$

30. **< HKCE 2009 Paper II - 25 >**

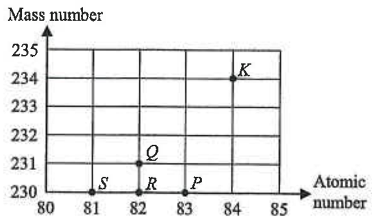
$$X \xrightarrow{\alpha} Y \xrightarrow{\beta} Z$$

The above shows part of a decay series. Which of the following deductions is/are correct ?
(1) X and Z are isotopes of the same element.
(2) X has two more neutrons than Z.
(3) Z has one more proton than Y.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

31. **< HKCE 2010 Paper II - 25 >**

The diagram shows the mass number and atomic number of a radioactive nuclide K. After undergoing the following decays, it becomes Z.



$$K \xrightarrow{\alpha} X \xrightarrow{\beta} Y \xrightarrow{\gamma} Z$$

Which of the following nuclides represents Z ?

A. P
B. Q
C. R
D. S

32. **< HKCE 2011 Paper II - 24 >**

A $^{238}_{92}$U nuclide undergoes a certain number of α and β decays and becomes $^{210}_{82}$Pb. Find the number of β particles emitted.

A. 2
B. 3
C. 4
D. 5

Part B : HKAL examination questions

33. **< HKAL 1981 Paper I - 33 >**

A stationary radioactive nucleus of mass number N emits an alpha particle, leaving a daughter nucleus of mass number $N - 4$. The ratio of the kinetic energy of the alpha particle to the kinetic energy of the daughter nucleus is

A. $(N - 4)/4$
B. $N^2/(N - 4)^2$
C. $(N - 4)^2/N$
D. $(N - 4)^2/4^2$

34. **< HKAL 1994 Paper IIA - 45 >**

A stationary U-238 nucleus undergoes α-decay. What is the ratio of the kinetic energy of the daughter nucleus to that of the α-particle ?

A. 238 : 4
B. 4 : 238
C. 234 : 4
D. 4 : 234

35. **< HKAL 1995 Paper IIA - 44 >**

$^{226}_{88}$Ra decays to $^{222}_{86}$Rn with a half-life of 1600 years. Which of the following statements is/are correct ?

(1) Alpha particle is given out in the decay.
(2) All $^{226}_{88}$Ra has decayed after 3200 years.
(3) The half-life of $^{226}_{88}$Ra can be shortened by heating.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

36. **< HKAL 1997 Paper IIA - 43 >**

$^{226}_{88}$Ra undergoes a series of decay to become the stable end-product $^{206}_{82}$Pb. What is the number of β-particles emitted in this series ?

A. 4
B. 6
C. 10
D. 14

37. **< HKAL 2009 Paper IIA - 44 >**

In β-decay, a neutron inside the nucleus changes into a proton and an electron, which is emitted as a β-particle. Radioactive nuclide plutonium $^{244}_{94}$Pu becomes lead $^{208}_{82}$Pb after a series of alpha and beta decays. Throughout the whole process, how many neutrons inside a $^{244}_{94}$Pu nucleus have undergone such change ?

A. 3
B. 6
C. 9
D. 12

38. **< HKAL 2010 Paper IIA - 42 >**

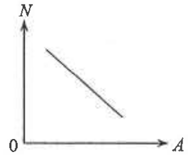
A radioactive source having a half-life of 5.3 years has an initial activity of 2500 Bq. A cancer treatment requires 10 seconds of irradiation of this source to give a certain number of radiation particles on a cancer site. If the same treatment is required after 2 years by this radioactive source, what should be the time of irradiation to give the same number of radiation particles ?

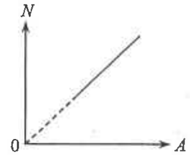
A. 13 s
B. 15 s
C. 18 s
D. 21 s.

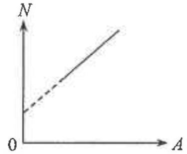
Part C : HKDSE examination questions

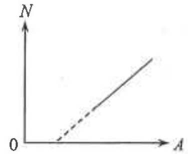
39. **< HKDSE 2012 Paper IA - 36 >**

Isotopes of an element have different mass number A and neutron number N. Which of the following $N - A$ plots correctly shows the relationship of N and A for any given element ?

A.


B.


C.


D.


40. **< HKDSE 2013 Paper IA - 34 >**

$^{238}_{92}$U undergoes α - β - β - α decay and becomes a nuclide X. What are the atomic number and mass number of X ?

	atomic number	mass number
A.	90	230
B.	90	234
C.	88	230
D.	88	234

41. **< HKDSE 2014 Paper IA - 31 >**

Nucleus W decays to nucleus Z as shown : $W \xrightarrow{\alpha} X \xrightarrow{\beta} Y \xrightarrow{\beta} Z$

Which of the following statements is/are correct ?

(1) Nucleus X has 1 more proton than nucleus Y.
(2) Nucleus W has 2 more neutrons than nucleus X.
(3) W and Z are isotopes of the same element.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

42. <HKDSE 2015 Paper IA - 33>

A piece of ancient wood is dated using carbon-14 dating method. It registers a corrected count rate of 11.0 counts per minute while a fresh wood sample cut from the same kind of trees gives a corrected count rate of 15.6 counts per minute. What is the approximate age of the wood found in the archaeological site ? Given : half-life of carbon-14 is 5730 years.

A. 890 years
B. 1300 years
C. 2000 years
D. 2900 years

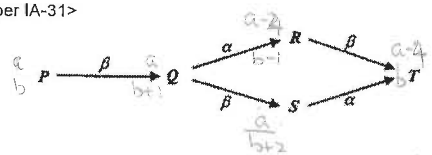
43. <HKDSE 2018 Paper IA - 32>

X and *Y* are two radioactive nuclides. The ratio of the mass of an atom of *X* to that of an atom of *Y* is 1 : 2. The half-lives of *X* and *Y* are *T* and 2*T* respectively. If two samples consisting of purely *X* and *Y* respectively have the same initial mass, find the ratio of the number of undecayed nuclei of *X* to that of *Y* after a period of 4*T*.

A. 1 : 4
B. 1 : 2
C. 1 : 1
D. 2 : 1

44. <HKDSE 2019 Paper IA-32>

45. <HKDSE 2020 Paper IA-31>



Nuclide *P* can decay into nuclide *T* through either process *P* – *Q* – *R* – *T* or process *P* – *Q* – *S* – *T* as shown. Which deductions below are correct ?

(1) *P* and *T* are isotopes of the same element.
(2) *Q* and *S* have the same number of protons.
(3) *S* has one more neutron than *R*.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

There is question in next page

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

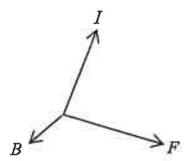
M.C. Answers

1. A	11. B	21. C	31. A	41. D
2. B	12. D	22. C	32. C	42. D
3. B	13. B	23. B	33. A	43. B
4. C	14. C	24. A	34. D	**44. B**
5. B	15. B	25. A	35. A	45. B
6. B	16. B	26. D	36. A	46. D
7. D	17. B	27. D	37. B	47. C
8. D	18. D	28. D	38. A	
9. B	19. A	29. C	39. D	
10. A	20. C	30. B	40. A	

M.C. Solution

1. A

The magnetic field is directed out of paper.
The magnetic force is towards the right.
By using Left-hand rule, the direction of current is upwards, that is same as the direction of motion.
Thus the radiation carries (+) charge, it must be α-particle.



$\therefore\ {}^{A}_{Z}\text{X} \rightarrow {}^{A-4}_{Z-2}\text{Y} + {}^{4}_{2}\text{He}$

2. B

× (1) Both have 17 protons.
✓ (2) No. of neutrons in ${}^{35}_{17}\text{Cl}$ = 35 – 17 = 18
No. of neutrons in ${}^{37}_{17}\text{Cl}$ = 37 – 17 = 20
× (3) Isotopes have identical chemical properties.

3. B

× (1) Isotopes have different number of neutrons but have same number of protons.
× (2) Different mass number represents different physical properties.
✓ (3) This is the definition of isotopes.

46. <HKDSE 2020 Paper IA-32>

The decay constant of a radioisotope of an element

A. is random.
B. depends on pressure and temperature.
C. is directly proportional to the number of nucleons in the isotope.
D. is an identifying characteristic of that isotope.

47. <HKDSE 2020 Paper IA-33>

Two radioactive samples P and Q are freshly prepared. It is found that when $\frac{15}{16}$ of all the nuclei of P have decayed, $\frac{63}{64}$ of all the nuclei of Q have also decayed. Find the ratio $\frac{\text{half-life of } P}{\text{half-life of } Q}$.

A. 1 : 4
B. 2 : 3
C. 3 : 2
D. 4 : 1

4. C

✓ (1) $^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$

✓ (2) $^{215}_{85}\text{At} \rightarrow {}^{211}_{83}\text{Bi} + {}^{4}_{2}\text{He}$

× (3) $^{210}_{83}\text{Tl} \rightarrow {}^{210}_{82}\text{Pb} + {}^{0}_{1}X$

5. B

Isotopes have different number of neutrons but have same number of protons, so as the electrons.

6. B

$20 \xrightarrow{\text{5700 years}} 10 \xrightarrow{\text{5700 years}} 5$

$\therefore$ Age of the wood = 5700×2

7. D

× (1) $^{230}_{90}X \rightarrow {}^{4}_{2}\text{He} + {}^{226}_{88}A$; since the atomic number of Y is 90, there must be β-decay in the series.

✓ (2) $^{230}_{90}X \rightarrow {}^{4}_{2}\text{He} + {}^{226}_{88}A \rightarrow {}^{0}_{-1}e + {}^{226}_{89}B \rightarrow {}^{0}_{-1}e + {}^{226}_{90}Y$

✓ (3) Both X and Y have the same atomic number 90.

8. D

Balancing the equation : $^{235}_{92}\text{U} \xrightarrow{^{4}_{2}\text{He}} {}^{231}_{90}\text{Th} \xrightarrow{^{0}_{-1}e} {}^{231}_{91}\text{Pa} \xrightarrow{^{4}_{2}\text{He}} {}^{227}_{89}\text{Ac}$

$X = \alpha$

$Y = \beta$

$Z = \alpha.$

9. B

Isotopes have different mass number but same atomic number, i.e. 50.

$\therefore$ $^{114}_{50}$X and Tin have the same atomic number and thus they are the same element.

10. A

$^{235}_{92}\text{U} \rightarrow {}^{207}_{82}\text{Pb} + x\,{}^{4}_{2}\text{He} + y\,{}^{0}_{-1}e$

Balancing the mass, $235 = 207 + 4x$ $\therefore\ x = 7$

Balancing the charge, $92 = 82 + 2(7) + y(-1)$ $\therefore\ y = 4$

11. B

× (1) number of protons = atomic number = 83

✓ (2) number of electrons = number of protons = 83

× (3) number of neutrons = mass number − atomic number = 214 − 83 = 131

12. D

$^{238}_{92}\text{U} \rightarrow {}^{A}_{Z}X + 2\,{}^{4}_{2}\text{He} + 2\,{}^{0}_{-1}e$

Balancing the mass number :

$238 = A + 2 \times 4$ $\therefore\ A = 230$

Balancing the atomic number :

$92 = Z + 2 \times 2 + 2 \times (-1)$ $\therefore\ Z = 90$

13. B

Upper number = Mass number of neutron = 1

Lower number = Charge of neutron = 0

14. C

Assume the mass number of W is 100 and the atomic number of W is 50. (OR any two arbitrary values)

$^{100}_{50}W \xrightarrow{^{0}_{-1}e} {}^{100}_{51}X \xrightarrow{^{4}_{2}\text{He}} {}^{96}_{49}Y \xrightarrow{^{0}_{-1}e} {}^{96}_{50}Z$

✓ (1) W and Z have the same atomic number, thus they are isotopes.

✓ (2) The atomic number of X is 51, which is the greatest among the above 4 nuclides.

× (3) The mass number of Y is 96, which is less than that of W and X, not the greatest.

15. B

✓ A. Carbon-14 dating makes use of the detection of β-radiation emitted by carbon for archaeological study

× B. Examination of fetuses makes use of ultrasound

✓ C. Killing cancer cells makes use of γ-rays

✓ D. Sterilization of food makes use of γ-rays

16. B

β particles are only partly absorbed by thin sheet of aluminium

$\therefore$ amount of β particles passing through depends on its thickness

$\therefore$ β can be used to check thickness of aluminium sheets

17. B

$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$

× (1) Number of neutron in $X = A - Z$
Number of neutron in $Y = A - (Z + 1)$

× (2) The number of protons in Y is greater than that in X by 1

✓ (3) Same mass number ⇒ same total numbers of neutrons and protons

18. D

$${}^{237}_{93}\text{Np} \xrightarrow{{}^{4}_{2}\text{He}} {}^{233}_{91}X \xrightarrow{{}^{0}_{-1}e} {}^{233}_{92}S$$

19. A

✓	A.	Age of ancient findings can be found by C-14 that emit β radiation with a constant half-life
×	B.	Use γ-rays to kill bacteria and germs
×	C.	Use α-radiation to ionize the air
×	D.	Use β-radiation to check thickness of aluminium sheets

20. C

Assume the atomic number of P is Z

Atomic number of $Q = Z - 2$

Atomic number of $R = Z - 2 + 1 = Z - 1$

Atomic number of $S = Z - 2 + 1 + 1 = Z$

Thus, P and S have the same atomic number, they are isotopes of the same element.

21. C

$${}^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{X} + {}^{4}_{2}\alpha$$

22. C

✓	(1)	carbon 14 dating is used to estimate the age of ancient remains
✓	(2)	gamma rays are used to kill bacteria in food
×	(3)	microwaves are used to transmit signals over long distances

23. B

Balancing the equation : ${}^{234}_{90}\text{Th} \longrightarrow {}^{206}_{82}\text{Pb} + x\,{}^{4}_{2}\alpha + y\,{}^{0}_{-1}\beta$

$234 = 206 + 4x \qquad \therefore \quad x = 7$

$90 = 82 + 2(7) + (-1)y \qquad \therefore \quad y = 6$

24. A

✓	(1)	The sources should have a short half-life so as to reduce the harmful effect to human bodies
✓	(2)	The radiation should have a weak ionizing power so that it can cause less harmful effect to human bodies
×	(3)	β-radiation, which can be deflected by an electric field, can be used as medical tracers. Since human bodies do not have electric field, this is not a criterion in choosing medical tracers.

25. A

γ source should be used

since it has great penetrating power to pass through the pipe wall and the ground to be detected.

The half life should be short in order to reduce the harmful effect to the environment.

26. D

The symbol of β is ${}^{0}_{-1}\beta$.

Thus the mass number of X is unchanged and the atomic number of X should be 91.

27. D

Since P and Y are two isotopes, they must have the same atomic number but different mass number.

Assume the atomic number of P and Y are both equal to n.

$${}_{n+2}X \xrightarrow{{}^{4}_{2}\alpha} {}_{n}Y \xrightarrow{{}^{0}_{-1}\beta} {}_{n+1}Z$$

$${}_{n}P \xrightarrow{{}^{0}_{-1}\beta} {}_{n+1}Q \xrightarrow{{}^{0}_{-1}\beta} {}_{n+2}R \xrightarrow{{}^{4}_{2}\alpha} {}_{n}S$$

✓	(1)	Both X and R have the same atomic number of $n + 2$.
✓	(2)	Both Y and S have the same atomic number of n.
✓	(3)	Both Z and Q have the same atomic number of $n + 1$.

28. D

After the foods have been exposed to γ radiations,

the foods will not become radioactive,

since there is no radioactive source in the foods.

29. C

The neutron interacts with nitrogen :

$${}^{1}_{0}\text{n} + {}^{14}_{7}\text{N} \rightarrow {}^{14}_{6}X + {}^{1}_{1}\text{H}$$

The equation for the nuclear reaction :

$${}^{14}_{6}X \rightarrow {}^{14}_{7}Y + {}^{0}_{-1}\beta$$

The final product Y is ${}^{14}_{7}\text{N}$

30. B

Assume the atomic number of X is 50 and the mass number of X is 100 :

$${}^{100}_{50}X \xrightarrow{{}^{4}_{2}\alpha} {}^{96}_{48}Y \xrightarrow{{}^{0}_{-1}\beta} {}^{96}_{49}Z$$

×	(1)	Since the atomic numbers of X and Z are not equal, they are not isotopes of the same element.
×	(2)	The number of neutrons of X is 50 and the number of neutrons of Z is $96 - 49 = 47$. Thus X should have 3 more neutrons than Z.
✓	(3)	The number of protons of Y is 48 and that of Z is 49, thus Z has one more proton than Y.

31. A

Mass number of K is 234 and atomic number of K is 84.

$${}^{234}_{84}K \xrightarrow{{}^{4}_{2}\alpha} {}^{230}_{82}X \xrightarrow{{}^{0}_{-1}\beta} {}^{230}_{83}Y \xrightarrow{\gamma} {}^{230}_{83}Z$$

The final product is P which has the mass number of 230 and atomic number of 83.

32. C

$238 = 210 + 4\alpha$ $\therefore \alpha = 7$

$92 = 82 + 2 \times 7 - \beta$ $\therefore \beta = 4$

33. A

$$KE = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m}$$

since the daughter nucleus and the α particle must have the same magnitude of momentum after the explosion

$$\therefore KE \propto \frac{1}{m}$$

$$\frac{KE_\alpha}{KE_{\text{nucleus}}} = \frac{m_{\text{nucleus}}}{m_\alpha} = \frac{N-4}{4}$$

34. D

$$KE = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m}$$

since the daughter nucleus and the α particle must have the same magnitude of momentum after the explosion

$$\therefore KE \propto \frac{1}{m} \quad \therefore \frac{KE_{\text{nucleus}}}{KE_\alpha} = \frac{m_\alpha}{m_{\text{nucleus}}} = \frac{4}{238-4} = \frac{4}{234}$$

35. A

✓ (1) Balancing the equation : ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{He}$.

× (2) It takes infinite time for all ${}^{226}_{88}\text{Ra}$ to decay.

× (3) Nuclear change cannot be changed by the surrounding temperature.

36. A

$${}^{226}_{88}\text{Ra} \rightarrow {}^{206}_{82}\text{Pb} + x\,{}^{4}_{2}\text{He} + y\,{}^{0}_{-1}e$$

Balancing the mass number,

$226 = 206 + 4x$ $\therefore x = 5$

Balancing the atomic number,

$88 = 82 + 2(5) + y(-1)$ $\therefore y = 4$

$\therefore$ 4 β-particles are emitted.

37. B

Consider the mass number : $244 = 208 + a(4)$ $\therefore a = 9$

There are 9 alpha particles emitted in the series.

Consider the atomic number : $94 = 82 + 9 \times (2) + b(-1)$ $\therefore b = 6$

There are 6 beta particles emitted in the series.

As each emission of beta particle involves a decay of neutron, there are 6 neutrons having such change.

38. A

The initial activity : $A_o = 2500$ Bq.

After two years, the activity A becomes : $A = (2500)\left(\frac{1}{2}\right)^{2/5.3} = 1925$ Bq

By $\Delta N = A\,\Delta t$ and same treatment needs the same number of radiation particles ΔN

$\therefore \Delta N = (2500) \times 10 = (1925) \times t$ $\therefore t = 13$ s

39. D

Let Z be the atomic number, which is equal to the number of protons.

$A = Z + N$ $\therefore N = A - Z$

Compared with $y = mx + c$, the graph is a straight line with slope +1 and with a negative y-intercept.

40. A

Atomic number of $X = 92 - 2 + 1 + 1 - 2 = 90$

Mass number of $X = 238 - 4 - 0 - 0 - 4 = 230$

41. D

$${}^{100}_{50}W \xrightarrow{\alpha} {}^{96}_{48}X \xrightarrow{\beta} {}^{96}_{49}Y \xrightarrow{\beta} {}^{96}_{50}Z$$

Assume that the atomic mass and atomic number of W is 100 and 50 respectively.

× (1) Nucleus X should have 1 less proton than nucleus Y.

✓ (2) Nucleus W has 2 more neutrons and 2 more protons than nucleus X.

✓ (3) Since W and Z have the same number of protons, they are isotopes of the same element.

42. D

Method ① : $C = C_o\left(\frac{1}{2}\right)^{t/t_{1/2}}$

$\therefore (11.0) = (15.6)\left(\frac{1}{2}\right)^{t/5730}$ $\therefore \log\left(\frac{11.0}{15.6}\right) = \log\left(\frac{1}{2}\right) \times \frac{t}{5730}$ $\therefore t = 2888 \approx 2900$ years

Method ② : $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{5730} = 1.21 \times 10^{-4}$ year^{-1}

By $C = C_o e^{-kt}$ $\therefore (11.0) = (15.6)\,e^{-(1.21\times10^{-4})\cdot t}$ $\therefore t = 2887 \approx 2900$ years

43. B

Initial number of atoms (nuclei) = $\dfrac{\text{Initial mass}}{\text{Mass of one atom}}$

Since the initial mass of X and Y are equal, initial number of undecayed nuclei $\propto \dfrac{1}{\text{Mass of one atom}}$

Since mass of one atom of X : mass of one atom of Y = 1 : 2

$\therefore$ initial number of nuclei of X : initial number of nuclei of Y = 2 : 1

Let the initial number of nuclei of X and Y be $2N_o$ and N_o respectively.

After a period of $4T$:

$$N_X = 2N_o \times \left(\frac{1}{2}\right)^{4T/T} = \frac{1}{8}N_o$$

$$N_Y = N_o \times \left(\frac{1}{2}\right)^{4T/2T} = \frac{1}{4}N_o$$

$\therefore N_X : N_Y = 1 : 2$

Use the following data wherever necessary :

Avogadro constant $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

The following list of formulae may be found useful :

Law of radioactive decay $N = N_0 e^{-kt}$

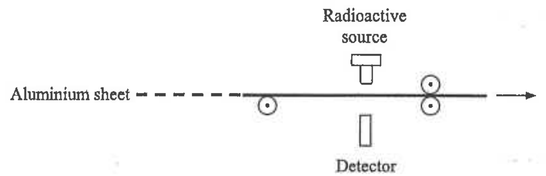
Half-life and decay constant $t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$

Activity and the number of undecayed nuclei $A = kN$

Part A : HKCE examination questions

1. **< HKCE 1980 Paper I - 9 >**

(a) A factory aims at producing aluminium sheets of 1 mm thickness. A radioactive source and a detector is used to monitor the thickness of the aluminium sheet manufactured as shown in the figure below.



(i) State what type of source (α, β or γ) should be used. (1 mark)

(ii) Explain briefly why the other two types of source are not used. (2 marks)

(b) Give TWO other applications of radioactivity. (2 marks)

2. < HKCE 1981 Paper I - 9 >

(a)

Figure 1

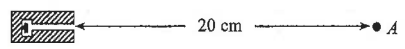
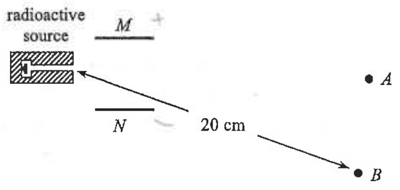


Figure 2



$^{238}_{92}U$ is a radioactive source giving α, β and γ radiations.

(i) If $^{238}_{92}U$ decays by emitting four α-particles and two β-particles, what will be the atomic number and mass number of the resulting nucleus ? (6 marks)

(ii) A GM counter is placed at *A* as shown in the Figure 1 about 20 cm from the source. What types of radiation can be received by the counter at *A* ? (2 marks)

(iii) An electric field is applied across the metal plates *M* and *N* as shown in the Figure 2 so that *M* is connected to the positive terminal and *N* is connected to the negative terminal of a voltage supply. The GM counter is now moved to *B* about 20 cm from the source. Describe and explain what happens to the count-rate. (2 marks)

(b) A volume of solution containing a radioactive isotope with an activity of 4400 Bq is now injected into the blood stream of a patient. After 20 hours the activity of 10 cm^3 of blood becomes 2 Bq. If the half-life of the isotope is 10 hours, estimate the volume of blood inside the person. (3 marks)

(c) If an α-particle is emitted from an atom of $^{224}_{88}Ra$ during the decay process, what will be the mass number and the atomic number of the daughter atom ? (2 marks)

3. < HKCE 1982 Paper I - 8 >

(a) What are the mass numbers of

(i) α-particles,

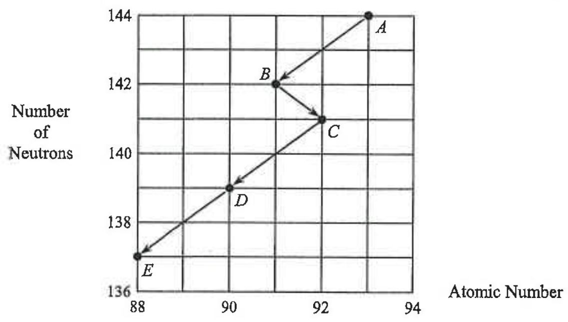
(ii) β-particles, and

(iii) neutrons ? (3 marks)

(b) The parent α source is $^{226}_{88}Ra$. If the daughter nucleus of Ra after α decay is *X*, write down the equation of the α-decay. (3 marks)

(c) If $^{234}_{91}X$ decays by emitting one α particle and one β particle to form a stable product nucleus *Y*, what will be the atomic number and mass number of *Y* ? (2 marks)

(d)



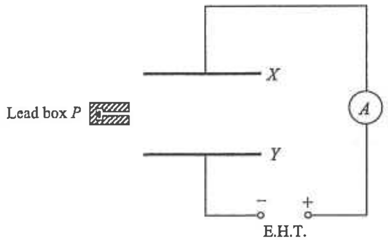
The above figure shows a radioactive decay series : $A \to B \to C \to D \to E$

(i) State what particles are emitted at each stage. (4 marks)

(ii) What is the mass number of *C* ? (1 mark)

4. < HKCE 1991 Paper I - 7 >

(a) Two metal plates X and Y are connected to a sensitive ammeter and an extra high tension supply (E.H.T.). A lead box P is placed near the metal plates as shown in the below figure.



(i) Sketch the electric field pattern between X and Y. The direction of the field should be shown. (2 marks)

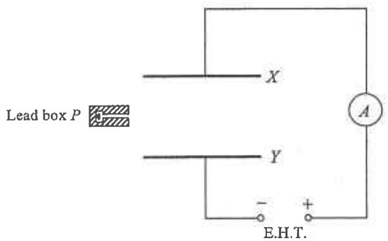
(ii) If a radioactive source emitting α particles is placed in P, the ammeter shows that a current is flowing. Explain why there is a current. (2 marks)

(iii) Explain what happens to the ammeter reading if the source in (ii) is replaced by one emitting γ rays ? (2 marks)

(iv) Suppose now a radioactive source $^{234}_{91}$Pa is placed in P. $^{234}_{91}$Pa decays by emitting a β particle and γ rays to form a daughter nucleus U.

(1) Write down an equation for the decay. (1 mark)

(2) On the below figure, sketch and label the paths of the radiation emitted by the source. (2 marks)



(b) Leaks in underground oil pipes can be detected by adding a small amount of radioactive source into the oil being pumped. Oil flows out from the leaks and radioactivity is detected on the ground around the leaks.

(i) Which type of source (α, β or γ) is suitable ? Explain briefly. (2 marks)

(ii) Two sources emitting the suitable type of radiation of half-lives 50 years and 10 hours are available. Which one should be used ? Explain briefly. (3 marks)

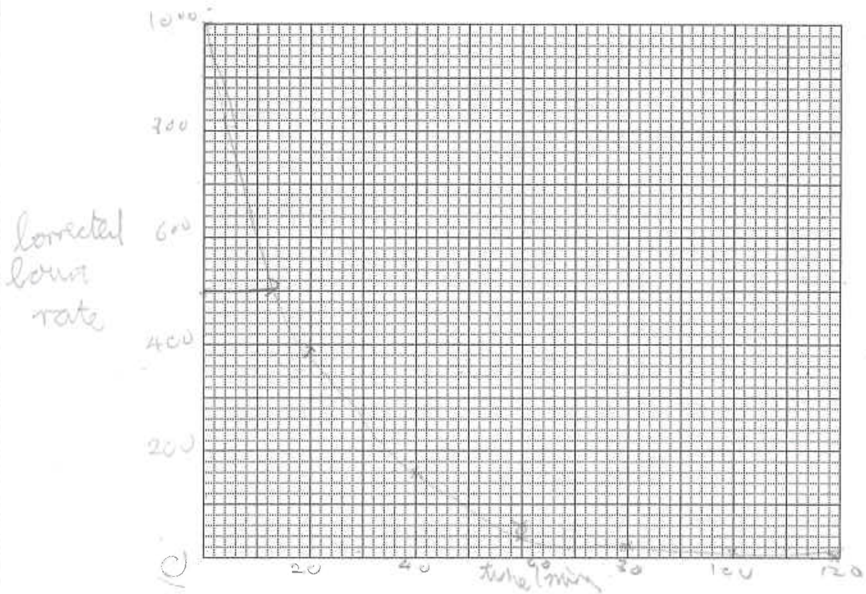
5. < HKCE 1993 Paper I - 7 >

In an experiment to measure the half-life of a radioactive isotope of sodium in a place where the background count rate is 100 counts per minute, the following result is obtained :

Time / hour	0	20	40	60	80	100	120
Total count rate/counts per min.	1100	498	259	161	125	110	104

(a) Suggest TWO major sources of background radiation. (2 marks)

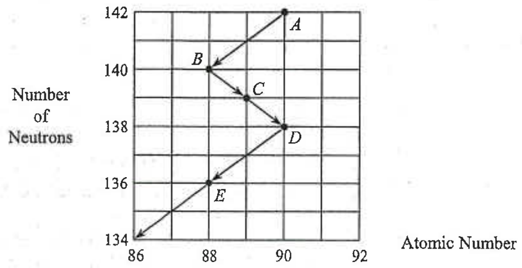
(b) Plot the graph of the CORRECTED count rate against time on graph paper. Hence find the half-life of the isotope. (6 marks)



(c) By considering its half-life, state whether the isotope is suitable to be used for injecting into a patient's vein so as to investigate his blood circulation. Give your reason. (3 marks)

6. < HKCE 1994 Paper I - 6 >

The below figure shows part of a decay series.



(a) From the figure, name the particle which is emitted in each of the following changes :

(i) $A \rightarrow B$

(ii) $B \rightarrow C$ (2 marks)

(b) State two nuclides in the series which are isotopes of each other. (1 mark)

(c) The final stable nuclide of the series is X, whose atomic number is 82 and the number of neutrons is 126.

(i) Find the mass numbers of A and X. (2 marks)

(ii) Find the total number of α particles emitted from A to X. (2 marks)

(d) Some of the nuclides in the figure also emit γ-radiation when they decay. However, it is impossible to identify these nuclides from the figure. Explain briefly. (2 marks)

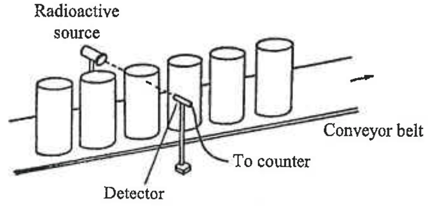
(e) A GM counter is placed 20 cm from a radioactive source which undergoes the decay as shown in the above figure. The corrected count rates obtained in three consecutive minutes are 1027, 1011 and 1018 counts per minute respectively.

(i) What type(s) of radiation emitted by the source can reach the counter ? Explain briefly. (2 marks)

(ii) Explain what is meant by a CORRECTED count rate. (2 marks)

(iii) Explain briefly why the three readings differ from each other. (2 marks)

7. < HKCE 1996 Paper I - 6 >



A factory produces detergent contained in plastic bottles. The following method is used to monitor the amount of detergent contained in each bottle : a radioactive source is placed on one side of the conveyor belt at the level to which the detergent is expected to fill and a detector is placed at the same level on the other side as shown in the figure above.

(a) Which type of radioactive source (α, β or γ) should be used ? Explain briefly why the other two types are not suitable. (3 marks)

(b) Suggest one suitable detector for the above system. (1 mark)

(c) Explain how the monitoring system can detect bottles of detergent that have not been filled up to the required level. (3 marks)

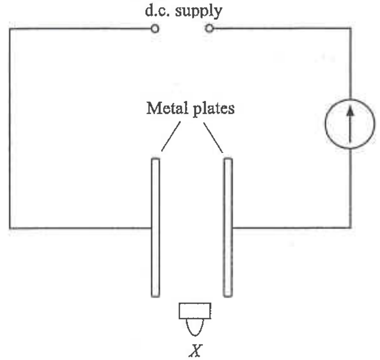
(d) Two sources emitting the suitable type of radiation of half-lives 10 minutes and 5 years are available.

(i) Explain what is meant by the half-life of a radioactive source. (2 marks)

(ii) Which source should be used ? Explain briefly. (3 marks)

(e) State two safety precautions that factory workers should take when handling radioactive sources. (2 marks)

8. < HKCE 1997 Paper I - 6 >



Two metal plates are connected to a high voltage d.c. supply and a galvanometer as shown in the Figure above. When a radioactive source X emitting α particles is placed very near the metal plates, the galvanometer shows that a current is flowing. When X is moved a small distance away from the two plates, the galvanometer reading quickly drops to zero.

(a) Explain why there is a current and why it is present only when X is very near the metal plates. (3 marks)

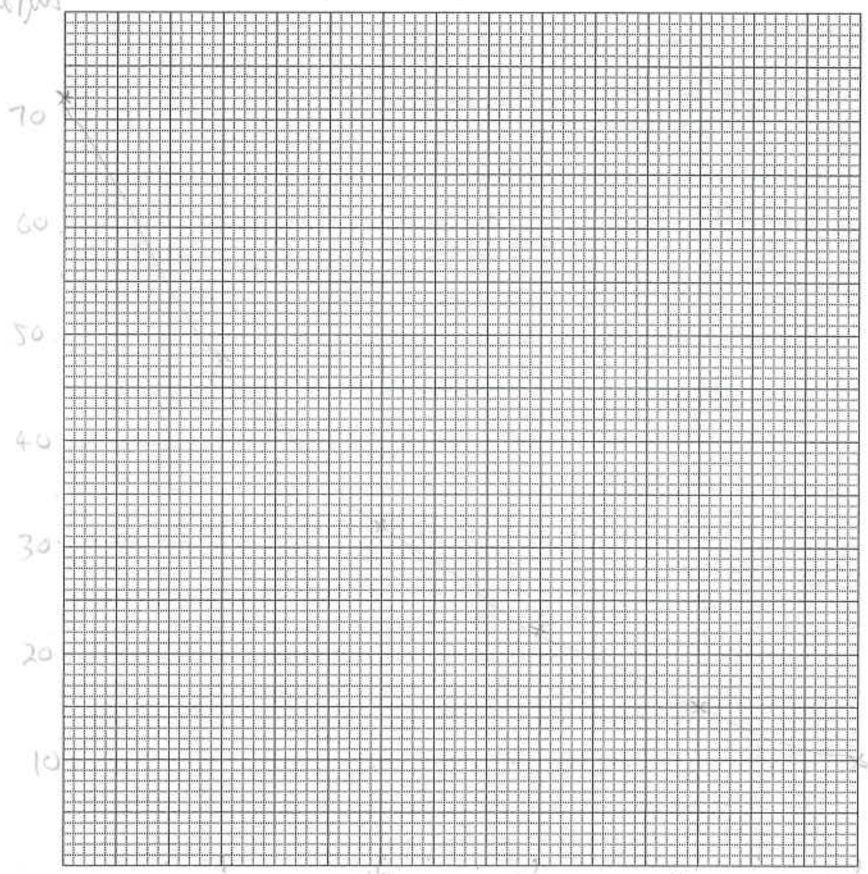
(b) ${}^{220}_{86}X$ decays by emitting an α particle to form a stable nucleus Y. Write down an equation for the decay. What is the neutron number of Y ? (3 marks)

(c) How would the galvanometer reading be affected if X is replaced by a β source ? Explain briefly. (2 marks)

8. (d) X is placed very near the metal plates and the galvanometer reading is recorded every 30 seconds. The results obtained are shown below :

Time / s	0	30	60	90	120	150
Current / μA	72	48	32	22	15	10

(i) Plot a graph of current against time on graph paper. (4 marks)



(ii) Hence find the half-life of X.

(Note : You may assume that the activity of the source is directly proportional to the current.) (1 mark)

(e) Explain why X is **not** suitable for use as tracers. (1 mark)

9. < HKCE 1998 Paper I - 6 >

The radioactive isotope of sodium, $^{24}_{11}$Na , decays by emitting a β particle to form a stable isotope of magnesium (Mg).

(a) Write down an equation for the decay. (2 marks)

(b) Suppose you are given the following apparatus :

a GM counter, a sheet of paper and a 5 mm thick aluminium sheet.

Describe how you can demonstrate that $^{24}_{11}$Na emits β particles and does not emit α particles. (4 marks)

(c) The half-life of $^{24}_{11}$Na is 15 hours. A sample of $^{24}_{11}$Na with an activity of 32×10^3 disintegrations per second is injected into the blood stream of a patient. After 45 hours, 6 cm^3 of blood is taken out from the patient's body and its activity is found to be 5 disintegrations per second.

(i) How many half-lives of $^{24}_{11}$Na will have elapsed after 45 hours ? (1 mark)

(ii) Estimate the volume of blood in the patient's body. (3 marks)

(iii) Suggest **two** reasons for using $^{24}_{11}$Na in this dilution test. (2 marks)

(d) State an application of radioactive isotopes, other than tracers, in each of the following fields :

(i) Medicine (1 mark)

(ii) Industry (1 mark)

10. < HKCE 2000 Paper I - 11 >

(a) X and Y are two radioactive nuclides with half lives of 12 hours and 2.6 years respectively. Both two nuclides decay by emitting a β particle to form stable product nuclides.

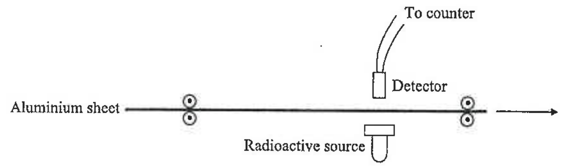
(i) After emitting a β particle, how would the atomic number and mass number of nuclide X be changed ? (2 marks)

(ii) Describe the changes in activity (in disintegrations per second) of a specimen of nuclide X and a specimen of Y after one day. (2 marks)

(iii) Comment on the following statement :

The mass of the specimen containing nuclide X will be reduced by approximately half in 12 hours. (2 marks)

(b) A factory produces aluminium sheets 1 mm in thickness. The thickness of the sheets is monitored by a gauge as shown in the figure below. A β source is used in the gauge.



(i) Explain why α and γ sources are not used in the gauge. (2 marks)

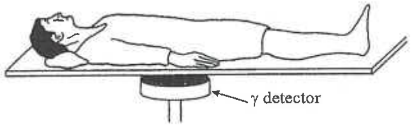
(ii) Which of the nuclides (X or Y) is more suitable to use as the radioactive source ? Explain your answer. (2 marks)

(iii) The count rate recorded should be around 90 counts per second when the thickness of the aluminium sheet is 1 mm. On a certain day when the gauge is operating properly, the following data are recorded :

Time / s	0	10	20	30	40	50	60	70	80	90	100
Recorded count rate / counts per s	90	89	91	90	90	88	66	64	90	89	89

Describe and explain the variation in the readings in the above table. (4 marks)

11. < HKCE 2002 Paper I - 10 >



Iodine-131 ($^{131}_{53}I$) is a radioisotope which decays by emitting a β-particle and γ rays. It is used in hospitals to test the kidneys of patients. During the test, an iodine-131 solution is injected into the bloodstream of a patient. As the blood passes through the kidney, iodine-131 will be absorbed by the kidney and eventually excreted out of the body with urine. If the kidney is not functioning properly, both the absorption and excretion rates of iodine-131 will decrease. A γ-detector is placed near the kidneys of the patient to detect the activity of the radiation coming from the kidneys as shown in the above figure.

(a) Using X to denote the daughter nucleus, write down an equation for the decay of an iodine-131 nucleus. (2 marks)

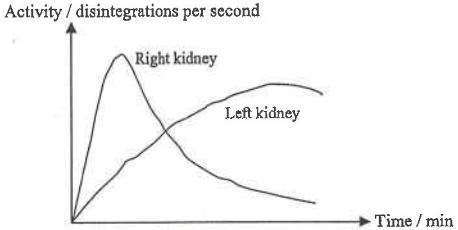
(b) Explain why the β-particles emitted by iodine-131 fail to reach the detector. (1 mark)

(c) The half-life of iodine-131 is 8 days.

(i) State the meaning of 'half-life'. (2 marks)

(ii) For safety purposes, the activity of iodine-131 solution in the test should not exceed 1.5×10^8 disintegrations per second. When an iodine-131 solution is prepared, its activity is 6×10^8 disintegrations per second. How many days after preparation would the solution be suitable for the test ? (2 marks)

(iii)



The above graph shows the variation of the activities of the radiation detected from the right and left kidneys of a patient with time. Which kidney do you think is **not** functioning properly ? Explain your answer. (3 marks)

(iv) Besides iodine-131, technetium-99*m* is another radioisotope that can be used in the kidney test. Technetium-99*m* emits γ radiation only and its half-life is 6 hours. Which of these two sources do you think is more preferable for use in the kidney test ? Explain your answer. (4 marks)

12. < HKCE 2004 Paper I - 9 >

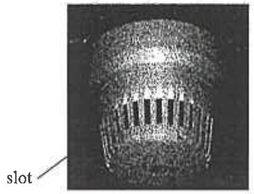


Figure 1

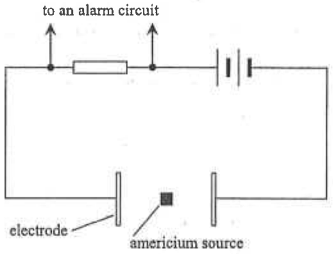


Figure 2

Figure 1 shows a smoke detector. The circuit inside the detector is shown in Figure 2. A small amount of the radioisotope americium-241 ($^{241}_{95}Am$) is placed between two electrodes. The two electrodes are connected to a battery and an alarm circuit. The detector has slots in it to allow air flow.

(a) An americium-241 nucleus decays by emitting an α-particle to form a daughter nucleus neptunium (Np), with a half-life of 432 years.

(i) Write down an equation for the decay of an americium-241 nucleus. (2 marks)

(ii) Find the number of neutrons in the daughter nucleus. (1 mark)

(b) Under normal conditions, a small current flows in the circuit inside the detector. However, when smoke particles enter the detector, the current drops significantly. This triggers the alarm to sound.

(i) Explain why a current flows between the electrodes under normal conditions. (3 marks)

(ii) Suggest one possible reason why the current drops when smoke particles enter the detector. (2 marks)

(c) Explain why it is preferable for the radioactive source used in smoke detectors to have a long half-life. (2 marks)

(d) Carbon-14 ($^{14}_{6}C$) is a radioisotope which decays by emitting β particles and has a half-life of 5700 years. Explain whether this source is suitable for use in smoke detectors or not. (2 marks)

(e) People are concerned about the biological hazards of radiation. If you are the manufacturer of the above described smoke detector, how would you explain to the public that using the detector will not pose any health hazard ? (2 marks)

13. < **HKCE 2005 Paper I - 7** >

Read the following passage about Iodine-131 therapy and answer the questions that follow.

> Iodine-131 is a radioisotope which emits β and γ radiation. It can be used for thyroid cancer treatment.
>
> A patient suffering from thyroid cancer will first undergo an operation to have the thyroid gland removed. However, some thyroid tissue may remain in the neck of the patient or may be carried in the blood stream to other parts of the body. Iodine-131 is then used to trace and get rid of the remaining thyroid tissue in the body.
>
> Iodine-131 therapy consists of two stages. In Stage 1, the patient will take a low dose of Iodine-131 to trace the remaining thyroid tissue. A detector is placed near the patient to monitor the activity of the radiation coming from the patient.
>
> In case any remaining thyroid tissue is spotted in Stage 1, the patient will then take a higher dose of Iodine-131 in Stage 2. The iodine will be absorbed by the thyroid tissue and the radiation emitted can kill the cancer cells.
>
> Special hospital rooms are designed for patients who receive Stage 2 of the therapy. The rooms have metallic shielding in the doors and reinforced walls. Inside the rooms, there are plastic covers on the furniture, doors, handles and switches.

Source : *Iodine-131 Therapy,* The Ohio State University Medical Center, 2003.

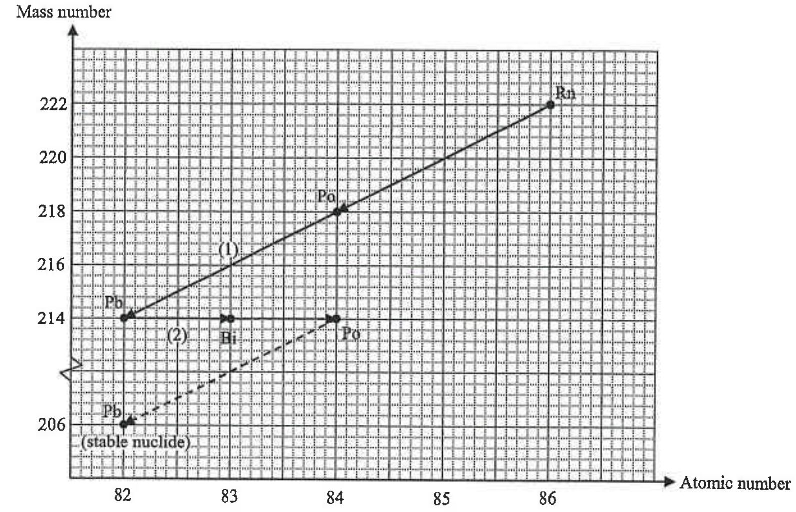
(a) Explain why, in Stage 1, β radiation from the patient cannot be detected by the detector. (1 mark)

(b) In Stage 2, which kind of radiation is more effective in killing cancer cells ? Explain your answer. (2 marks)

(c) State one special feature of the hospital rooms designed for patients receiving Stage 2 of the therapy and explain its function. (2 marks)

14. < **HKCE 2009 Paper I - 7** >

Radon-222 (Rn-222) has a half-life of 3.8 days and undergoes a radioactive decay series as shown in the Figure below to become a stable nuclide Lead-206 (Pb-206).



(a) Estimate the mass of undecayed Rn-222 after 15.2 days if its initial mass is 1×10^{-5} g. (2 marks)

(b) State the nuclear radiation emitted in process (1) indicated in the above Figure. (1 mark)

(c) Write down a nuclear equation for process (2) indicated in the above Figure. (2 marks)

(d) Determine the total number of α particles and the total number of β particles emitted in the radioactive decay series from Rn-222 to Pb-206. (4 marks)

15. **< HKCE 2010 Paper I - 8 >**

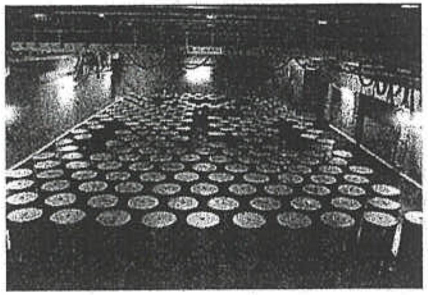
Read the following passage about low-level radioactive waste and answer the questions that follow.

Low-level Radioactive Waste

Industrial, medical and educational institutions in Hong Kong generate small amounts of low-level radioactive waste. Such waste produces no detectable heat output and is of low radioactive level. Weakened radiation sources from hospitals and educational institutions are examples of low-level radioactive waste.

For many years, most of the waste had been stored in disused tunnels and hospitals. The Government considers that in the long run the low-level radioactive waste should be stored in a purpose-built facility. After about two years of construction, the Low-level Radioactive Waste Storage Facility (the Facility) (see the Figure below) at Siu A Chau, an uninhabited island to the southwest of Lantau Island, was successfully commissioned and began its operation in July 2005. It comprises a shielded waste storage vault, a fully equipped laboratory. an automatic control room, an advanced wastewater treatment plant and specially designed waste reception and processing area. The radiation levels inside and outside the Facility are continuously monitored to ensure safe operation.

The Low-level Radioactive Waste Storage Facility at Siu A Chau - Storage Vault



(a) State **one** characteristic of low-level radioactive waste. (1 mark)

(b) Explain why Siu A Chau is suitable for the storage of low-level radioactive waste. (1 mark)

(c) Suggest an instrument to monitor the radiation levels inside and outside the Facility. (1 mark)

(d) In hospitals, radioactive sources are used as tracers. The radioactive source is injected into a patient's body and the radiation level is monitored with detectors outside the body. Explain why γ source is suitable for using as tracers. (2 marks)

16. **< HKCE 2010 Paper I - 7 >**

Carbon-14 dating can be used to identify the age of some objects. Living organisms contain a constant proportion of carbon-14. After an organism dies, the amount of carbon-14 in it decreases due to decays. We can estimate the age of an object by measuring the activity of carbon it contains.

(a) Carbon-14 undergoes decay as shown in the following nuclear equation, where D denotes the daughter nucleus.

$${}^{14}_{6}C \rightarrow {}^{y}_{x}D + \beta$$

Find the values of x and y. (2 marks)

(b) In a piece of wood found, the activity of 10 g of carbon is 35 disintegrations per minute. It is known that the activity due to 10 g of carbon in a living plant is 140 disintegrations per minute. Estimate the age of this piece of wood. Given that the half-life of carbon-14 is 5700 years. (3 marks)

17. **< HKCE 2011 Paper I - 7 >**

It is known that plutonium-238 (${}^{238}_{94}Pu$) decays by emitting one α particle.

(a) Write a nuclear equation for the decay of plutonium-238. Use the symbol Y as the daughter nucleus. (2 marks)

(b) A sample of plutonium-238 is put in a cloud chamber. Some tracks are seen.

(i) Describe the tracks that are seen. (1 mark)

(ii) No tracks can be seen when the sample is covered by a piece of paper. Explain. (2 marks)

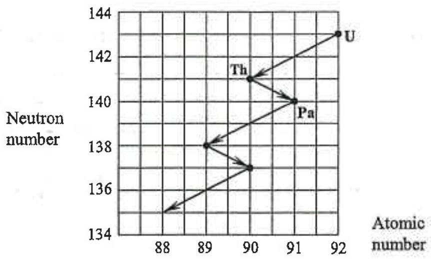
(c) Plutonium-238 can be used in heater units in spacecrafts for outer space missions. It is known that the power of the heater unit is directly proportional to the activity of plutonium-238 contained. Each heater unit has a power of 2 W when it is newly manufactured. How long can a newly manufactured heater unit last if the minimum power output required is 0.25 W ?

Given : half-life of plutonium-238 = 87.7 years (3 marks)

Part B : HKAL examination questions

18. **< HKAL 1993 Paper IIB - 12 >**

The figure below shows the decay series for an isotope of uranium : ${}^{235}_{92}U$.



(a) Name the particles emitted when

(i) Uranium (U) decays to Thorium (Th); and (1 mark)

(ii) Thorium (Th) decays to Protactinium (Pa). (1 mark)

(b) Given that the half-life of ${}^{235}_{92}U$ is 7.1×10^8 years, what would be the percentage of ${}^{235}_{92}U$ left in a sample after a period of 10^8 years ? (3 marks)

19. **< HKAL 1995 Paper I - 10 >**

The age of a sample of rock containing potassium-40 can be estimated by observing its activity. Potassium-40 decays to give the stable isotope of Argon. The activity of a sample is found to be 1.6 Bq while the original activity of a similar rock having the same mass is 4.8 Bq. The half-life of potassium-40 is 1.3×10^9 years.

(a) (i) Find the decay constant of potassium-40. (2 marks)

(ii) Give the physical meaning of the decay constant of a radioactive isotope. (2 marks)

19. (b) Find the age of the rock sample. (2 marks)

(c) Give **two** factors that determine the activity of a radioactive source. (2 marks)

20. **< HKAL 2009 Paper I - 8 >**

Carbon-14 dating is used in archaeological study to determine the age of an ancient sample.

(Given : mass of one mole of carbon-12 = 12.0 g and half-life of carbon-14 = 5730 years)

(a) (i) Calculate the decay constant k, in s^{-1}, of carbon-14. (2 marks)

(ii) The relative abundance of carbon-14 in living things is only one carbon-14 atom for every 7.2×10^{11} atoms of carbon-12. Calculate the activity for 1 g of carbon in living things. (3 marks)

(b) (i) Explain the origin of carbon-14 in the atmosphere and why the abundance of carbon-14 in living things, such as plants, remains more or less constant. (3 marks)

(ii) An archaeologist measured an activity of 2 Bq from 60 g of carbon in a piece of ancient bone. Use the result in (a), estimate the age of the bone. (3 marks)

Part C : HKDSE examination questions

21. **< HKDSE 2013 Paper IB - 9 >**

Carbon-14 dating can be used to identify the age of some objects which have the ^{14}C isotope, as it is radioactive and decays by emitting a β-particle. A piece of wood sample is examined using carbon-14 dating and its activity is 0.2 Bq. The half-life of ^{14}C is 5730 years. Given : 1 year = 3.16×10^7 s

(a) Calculate the decay constant of ^{14}C in s^{-1}. Hence find the number of ^{14}C nuclei in this wood sample. (3 marks)

Assume that living organisms contain a constant proportion of carbon-14 in the ratio of $^{14}C / ^{12}C = 1.3 \times 10^{-12}$ during its life time via intake of carbon dioxide (CO_2) from the atmosphere.

(b) The carbon content of this wood sample is found to contain a total of 1×10^{23} carbon nuclei. Estimate the number of ^{14}C nuclei in the sample originally when it died. (1 mark)

(c) Estimate the age of this wood sample in years using the results found in (a) and (b). (2 marks)

22. **< HKDSE 2016 Paper IB - 9 >**

Part of the decay series of uranium-238 (U-238) is shown below. The end product lead-206 (Pb-206) is stable.

$$^{238}_{92}U \xrightarrow[4.5 \times 10^9 \text{ years}]{\alpha} Th \xrightarrow[21 \text{ days}]{\beta} Pa \longrightarrow \dots \longrightarrow ^{206}_{82}Pb$$

(a) When a U-238 nucleus decays to a Pb-206 nucleus, how many α-particle(s) and β-particle(s) are emitted ? (2 marks)

(b) As the first decay in the above chain from U to Th has a half-life much longer than those of subsequent decays, the decay from U-238 to Pb-206 can be simplified to a *single decay* with half-life 4.5×10^9 years :

$$^{238}_{92}U \xrightarrow[4.5 \times 10^9 \text{ years}]{} ^{206}_{82}Pb$$

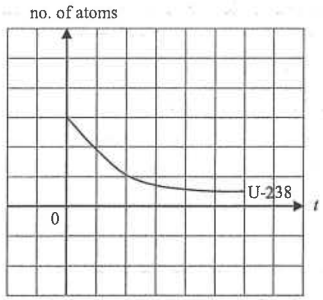
Suppose that a uranium-bearing rock contains only U-238 and no Pb-206 at the time when it was formed long ago by solidification of molten material. In a particular sample of the rock, it is found that *at present*, the ratio :

$$\frac{\text{number of Pb-206 atoms}}{\text{number of U-238 atoms}} = \frac{2}{3}$$

(i) Estimate the age of the rock. Assume that all Pb-206 atoms come from the decay of U-238 originally present in the sample and ignore the small number of U-238 atoms which have decayed but have not yet become Pb-206. (2 marks)

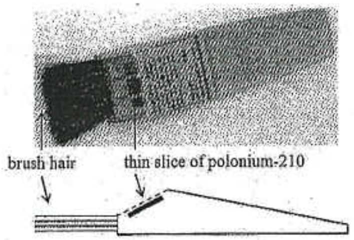
(ii) State, with a reason, whether the answer in (b) (i) is an overestimate or underestimate of the age of the rock if some Pb-206 atoms have actually been lost. (2 marks)

(iii) The graph in the Figure below shows how the number of U-238 atoms in the sample varies with time t subsequently while t = 0 denotes the present time. On the same Figure, sketch a graph to show the variation of the number of Pb-206 atoms in the sample with time. (2 marks)



23. **< HKDSE 2017 Paper IB - 10 >**

Dust may adhere to the surfaces of photos and films due to electrostatic attraction. To remove the dust effectively, a special brush with a thin slice of polonium-210 ($^{210}_{84}$Po) fixed near the brush hair as shown in the below Figure may be used. Polonium-210 undergoes α decay and the daughter nucleus lead (Pb) is stable.



(a) Write a nuclear equation for the decay of polonium-210. (2 marks)

(b) Briefly explain how the α particles help clean the charged dust. (2 marks)

(c) Briefly explain why the polonium-210 slice must be fixed near to the brush hair. (1 mark)

(d) The manufacturer recommends that the brush should be returned to the factory for replacement of the polonium-210 slice every year. Taking the activity of a newly replaced polonium-210 slice as 1 unit, find its activity after one year (365 days). Given: half-life of polonium-210 is 138 days. (2 marks)

24. **< HKDSE 2018 Paper IB - 10 >**

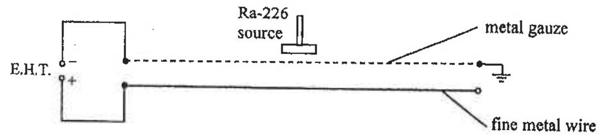
(a) Part of the decay series of radium-226 (Ra-226) is shown below. Ra-226 decays to radon (Rn) by emitting an α particle with half-life 1600 years. The end product in the series is lead (Pb), which is stable.

$$^{226}_{88}\text{Ra} \xrightarrow{\alpha} \text{Rn} \longrightarrow \ldots \longrightarrow \text{Pb}$$

(i) $^{206}_{82}$Pb, $^{207}_{82}$Pb and $^{208}_{82}$Pb are three stable isotopes of lead. State, with a reason, which isotope can be the end product in this series. (2 marks)

(ii) In a certain laboratory, a Ra-226 source has been used for 50 years. Estimate the percentage of undecayed Ra-226 left after this period. (2 marks)

(b) Spark counter can show the ionizing power of radiations. The Figure indicated the main features of a type of spark counter in school laboratories.



A spark counter consists of a fine metal wire mounted a few mm beneath an earthed metal gauze. The wire is connected to the positive terminal of an E.H.T. (Extra High Tension) supply so that a very intense electric field is set up between the wire and the metal gauze. When a Ra-226 source is brought near the gauze, sparks giving out flashes of light and crackling sound are produced at irregular intervals.

(i) Explain why the sparks occur at **irregular** intervals. (1 mark)

A Ra-226 source used in school laboratories is usually said to emit α, β as well as γ radiations.

(ii) Explain why β radiation is also emitted even though the source is primarily an α-emitter. (1 mark)

(iii) Why is the sparking mainly caused by α radiation rather than β or γ radiation ? Suggest a simple way to verify this. (2 marks)

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

Question Solution

1. (a) (i) β should be used. [1]

(ii) α is not used because it is totally absorbed by the aluminium sheet [1]

OR

α is not used because its penetrating power is too weak that it cannot pass through aluminium sheet. [1]

γ is not used because the count rate would not be affected significantly by the aluminium sheet. [1]

OR

γ is not used because its penetrating power is too strong that almost all γ will pass through the sheet. [1]

(b) Any **TWO** of the following : [2]

- radiotherapy
- estimate the age of archaeological samples
- medical tracer
- sterilization
- leakage test of underground oil pipes
- smoke detection

[Note : Thickness gauge is NOT acceptable since it is the application in part (a).]

2. (a) (i) Atomic number of resulting nucleus $= 92 - 4 \times 2 + 2$ [2]

$= 86$ [1]

Mass number of resulting nucleus $= 238 - 4 \times 4$ [2]

$= 222$ [1]

(ii) β and γ [2]

(iii) Count-rate decreases [1]

since only background radiation can be detected at point B [1]

(b) After 20 hours : $A = 4400 \times \left(\frac{1}{2}\right)^2 = 1100$ [1]

By $\frac{10}{V} = \frac{2}{1100}$ [1]

$\therefore$ Volume of blood $= 5500 \text{ cm}^3$ [1]

(c) Mass number $= 224 - 4 = 220$ [1]

Atomic number $= 88 - 2 = 86$ [1]

3. (a) (i) mass number of $\alpha = 4$ [1]

(ii) mass number of $\beta = 0$ [1]

(iii) mass number of neutron $= 1$ [1]

(b) ${}^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}X + {}^{4}_{2}\alpha$ [3]

(c) atomic number $= 91 - 2 + 1 = 90$ [1]

mass number $= 234 - 4 = 230$ [1]

(d) (i) $A \longrightarrow B$: α particle [1]

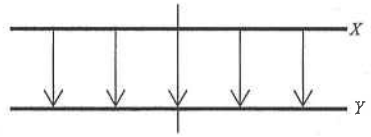
$B \longrightarrow C$: β particle [1]

$C \longrightarrow D$: α particle [1]

$D \longrightarrow E$: α particle [1]

(ii) Mass number of $C = 141 + 92 = 233$ [1]

4. (a) (i)



< Direction of electric field lines is downwards > [1]

< The electric field lines are parallel and evenly spaced > [1]

(ii) Air molecules are ionized by α particles. [1]

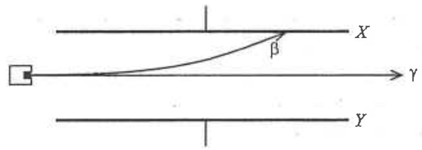
The ions then move to the metal plates to conduct a current. [1]

(iii) The ammeter reading decreases ; (OR becomes zero) [1]

since the ionizing power of γ radiation is very weak. [1]

(iv) (1) ${}^{234}_{91}\text{Pa} \longrightarrow {}^{234}_{92}\text{U} + {}^{0}_{-1}\beta + \gamma$ [1]

(2)



< β is deflected upwards > [1]

< γ is not deflected > [1]

4. (b) (i) A γ source should be used. [1]
Since the penetrating power of γ is high enough to reach the ground. [1]

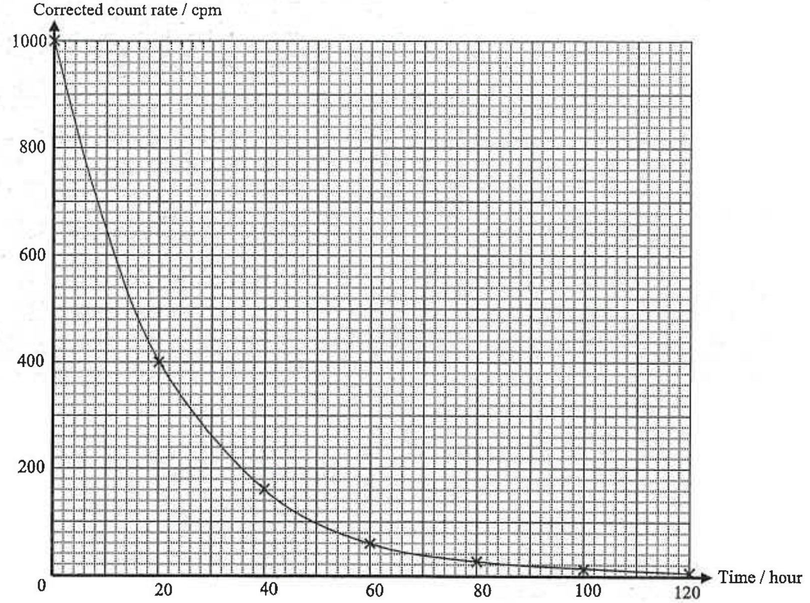
(ii) The source with half life 10 hours should be used. [1]
Reason : (Any **ONE** of the following) [2]
* It gives less pollution to the environment as its activity disappears quickly
* It causes less harmful effect to the environment as its activity disappears quickly

5. (a) Any **TWO** of the following : [2]
* Cosmic radiation from the space
* Radiation from the rocks
* Radiation from air
* Radiation from food

(b)

Time / hour	0	20	40	60	80	100	120
Corrected count rate / cpm	1000	398	159	61	25	10	4

[1]



< Two axes labelled correctly > [1]
< Suitable scales chosen > [1]
< At least 5 points plotted correctly > [1]
< Smooth curve drawn > [1]

5. (b) Half-life = 15 hours < 14 – 16 hours is acceptable > [1]

(c) Yes, it is suitable [1]
The half-life is long enough for the doctor to diagnose the patient. [1]
The half-life is short enough to cause less harmful effect on the patient. [1]
OR
The half-life is not too short [1]
and not too long. [1]

6. (a) (i) α particle [1]
(ii) β particle [1]

(b) A and D are isotopes of each other. (**OR** B and E) [1]

(c) (i) Mass number of A = 142 + 90 = 232 [1]
Mass number of X = 126 + 82 = 208 [1]

(ii) Total number of α particles emitted $= \dfrac{232 - 208}{4}$ [1]
$= 6$ [1]

(d) γ emission does not change the atomic number and mass number of the nuclide. [2]

(e) (i) β and γ radiation can reach the counter because their ranges in air are longer than 20 cm. [2]
(ii) A corrected count rate is equal to the recorded count rate minus the background count rate. [2]
(iii) The readings differ due to the random nature of radiation. [2]

7. (a) A β source should be used. [1]
An α source is not suitable because α particles cannot pass through the container. [1]
A γ source is not suitable because γ radiation is too penetrating. [1]
(**OR** cannot be absorbed by the container)

(b) A GM tube (**OR** Geiger Muller tube) (**OR** GM counter) can be used. [1]

(c) If a bottle not filled up to the required level passes the source,
the counter will record a much higher reading than that when an acceptable bottle passes the source, [2]
since the β radiation does not pass through the detergent and hence is not absorbed. [1]

7. (d) (i) The half-life is the time taken for half of the number of undecayed nuclei in the source to decay. [2]

OR

The half-life is the time taken for the activity of the source to fall to half of its initial value. [2]

OR

The half-life is the time taken for the mass of the undecayed nuclei in the source to decay. [2]

(ii) The source with half-life 5 years should be used. [1]

Reason : (ANY ONE) [2]

* The source will decay slowly and can be used for a long time.
* The activity of the source will be very stable to be used for a long time.
* The source with half-life 10 minutes will decay rapidly and the registered count rate is unstable even when no bottles are present.

(e) Any **TWO** of the followings : [2]

* Wearing film badges or other detecting devices
* Working behind lead-glass windows
* Handling radioactive sources using special forceps (**OR** remote controlled robots)
* Wearing protective coveralls
* Radioactive sources should not be pointed towards human bodies
* Radioactive sources should be stored in lead castles and returned to the storage box after use
* Workers should wear disposable gloves to handle the radioactive sources

8. (a) Some air molecules are ionized by the α-particles. [1]

The ions then move to the two respective plates to form a current. [1]

As α-particles have a very short range in air, the source must be placed very close to the plates. [1]

(b) $^{220}_{86}\text{X} \longrightarrow {}^{216}_{84}\text{Y} + {}^{4}_{2}\alpha$

< Mass number and atomic number of Y are correct > [1]

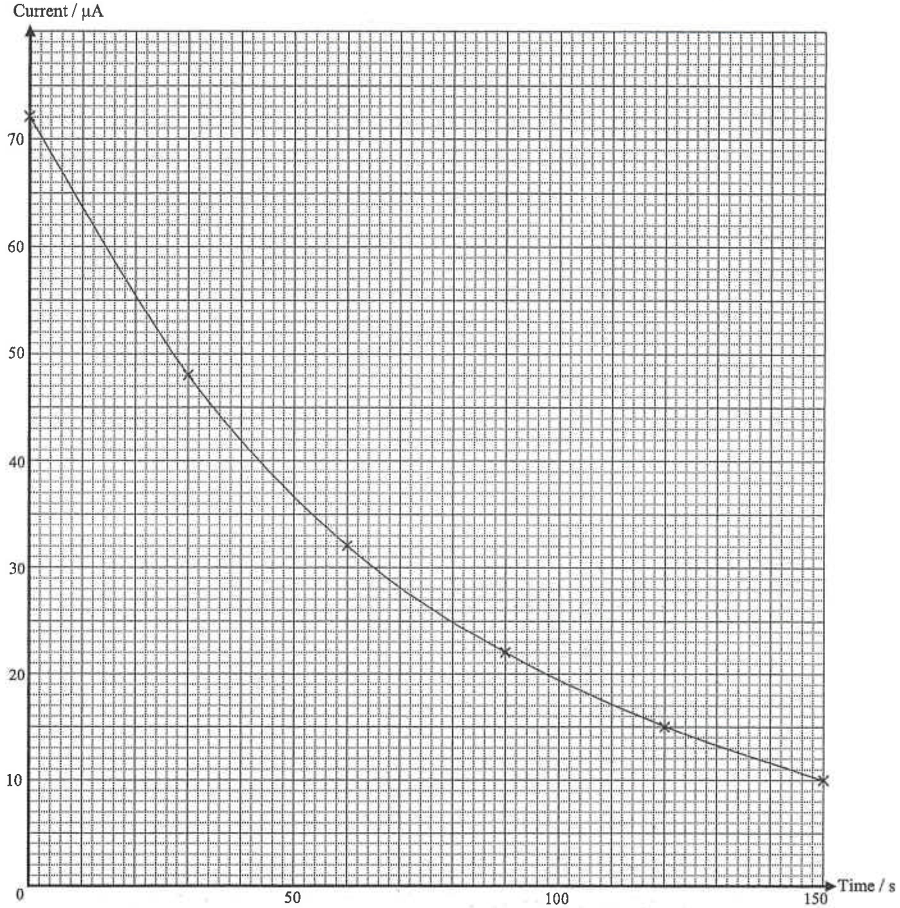
< Equation is correct > [1]

The neutron number of Y is 132. [1]

(c) The galvanometer reading decreases (**OR** becomes very small) [1]

because the ionizing power of β-particles is weaker. [1]

8. (d) (i)



< Labelled axes with units > [1]

< An appropriate scale > [1]

< Correct points plotted > [1]

< Smooth curve > [1]

(ii) From the graph, the half-life of the source is 52 s. [1]

< from 50 s to 54 s is acceptable >

(e) Any **ONE** of the following : [1]

* The penetrating power of α-particles is too low to be used as tracers.
* The half-life of X is too short to be used as tracers.

9. (a) $^{24}_{11}Na \longrightarrow ^{24}_{12}Mg + ^{0}_{-1}\beta$ [2]

(b) The GM tube is held close from the source and its reading is noted. [1]
Insert a piece of paper between the GM tube and the source. [1]
The count rate would remain unaffected. This shows that the source does not emit α particles. [1]
Insert the aluminium sheet between the tube and the source. The count rate would drop significantly. [1]
This shows that the source emits β particles.

(c) (i) Number of half-lives elapsed $= \frac{45}{15} = 3$ [1]

(ii) Total activity in the blood of the patient after 45 hours $= 32 \times 10^3 \times \left(\frac{1}{2}\right)^3 = 4000$ [1]

$\therefore \frac{V}{6} = \frac{4000}{5}$ [1]

$\therefore V = 4800 \text{ cm}^3$ [1]

(c) (iii) Any **TWO** of the following : [2]
- ✶ The half-life is long enough for medical diagnosis.
- ✶ The half-life is short enough to reduce the harmful effect to the human body.
- ✶ The daughter nuclei Mg is stable and has no harmful effect.
(**OR** Sodium and magnesium have no harmful chemical effects on human body.)

(d) (i) Any **ONE** of the followings : [1]
- ✶ Radiotherapy
- ✶ Medical tracer
- ✶ Sterilization of medical equipment

(ii) Any **ONE** of the followings : [1]
- ✶ Thickness gauge
- ✶ Food preservation (Sterilization of beef)
- ✶ Leakage detection
- ✶ Radioactive lightning conductor
- ✶ Smoke detector

10. (a) (i) The atomic number increases by one. [1]
The mass number remains unchanged. [1]

(ii) The activity of specimen *X* will fall to a quarter of its original value. [1]
The activity of specimen *Y* will remain approximately unchanged. [1]

(iii) As the mass of β particles emitted is very small, [1]
the mass of the specimen would almost remain unchanged after 12 hours. [1]

10. (b) (i) α source is not used because the penetrating power of α particles is too low. [1]
γ source is not used because the penetrating power of γ radiation is too high. [1]

(ii) Nuclide *Y* is more suitable. [1]
As nuclide *Y* has a longer half-life, its activity remains stable over a longer period of time. [1]

(iii) The reading remains steady from $t = 0$ to 50 s and from $t = 80$ to 100 s. [1]
The small variation within this period is due to the random nature of radioactive decay. [1]
The reading drops significantly from $t = 60$ to 70 s. [1]
The aluminium sheet in this period is thicker than the normal value. [1]

11. (a) $^{131}_{53}I \longrightarrow ^{131}_{54}X + ^{0}_{-1}\beta$ **OR** $^{131}_{53}I \longrightarrow ^{131}_{54}X + ^{0}_{-1}\beta + \gamma$ [2]

(b) The β particles fail to pass through the human body. [1]

OR

The β particles are absorbed by the human body. [1]

(c) (i) The half-life is the time taken for the activity of the source to drop to half of its initial value. [2]

(ii) No. of half-life = 2 [1]
The solution is suitable after $2 \times 8 = 16$ days [1]

(iii) The left kidney is not functioning properly [1]
since the activity in the left kidney increases at a lower rate. [2]

(iv) Technetium-99*m* is more preferable than iodine-131 for use in the test. [1]
Since technetium-99*m* has a shorter half-life [1]
and does not emit β particles, [1]
so it causes less harmful effect to the patient. [1]

12. (a) (i) $^{241}_{95}Am \longrightarrow ^{237}_{93}Np + ^{4}_{2}\alpha$ [2]

(ii) Number of neutrons $= 237 - 93 = 144$ [1]

(b) (i) The α-particles will ionize the air to give ions. [2]
The ions then move to the electrodes to give a current. [1]

(ii) The smoke particles block the movement of the charged particles. [1]
As a result, fewer ions reach the electrodes, so the current drops. [1]

12. (c) The activity of the source will remain stable for a long period of time. (**OR** decay very slowly) [1]
So the detector can be used for a longer timer. (**OR** The source needs not be replaced frequently.) [1]

(d) As β particles have a weaker ionizing power, [1]
the current flowing between the electrodes will be extremely small. [1]
So Carbon-14 is not suitable.

(e) Any **ONE** of the following : [2]
* The radiation dose from the smoke detector is very small.
* The radiation from the smoke detector is much less than the background radiation.
* The source used in the smoke detector is a very weak source.
* α-particles have a very short range in air.

13. (a) The penetrating power of β radiation is too low. [1]
OR
β radiation cannot penetrate through human body. [1]

(b) β radiation is more effective in killing cancer cells. [1]
Since the ionizing power of β is higher than that of γ radiation. [1]

(c) The rooms have metallic shielding in the doors and walls. [1]
They can prevent radiation from leaking out of the rooms. [1]
OR
Inside the rooms, there are plastic covers on the furniture, doors, handles and switches. [1]
This prevents other persons using the room from being contaminated. [1]

14. (a) Number of half-lives $= \dfrac{15.2}{3.8} = 4$ [1]

Mass of Rn-222 left $= 1 \times 10^{-5} \times (\frac{1}{2})^4 = 6.25 \times 10^{-7}$ g [1]

(b) α [1]

(c) $^{214}_{82}\text{Pb} \rightarrow {}^{214}_{83}\text{Bi} + {}^{0}_{-1}\beta$ [2]

(d) Let a and b be the number of α particles and β particles respectively.
$222 - 206 = 4a$ [1]
$a = 4$ [1]
$86 - 82 = 4 \times 2 - b$ [1]
$b = 4$ [1]

15. (a) It produces no detectable heat output. [1]
OR
It has a low radioactive level. [1]

(b) It is because it is an uninhabited place. [1]

(c) GM counter (**OR** GM tube) [1]
OR
photographic film [1]

(d) It has weak ionizing power [1]
and causes less harmful effect to the human body. [1]
OR
It has strong penetrating power [1]
and can pass through the body to be detected outside the body. [1]

16. (a) $x = 7$ [1]
$y = 14$ [1]

(b) $35 = 140\left(\dfrac{1}{2}\right)^n$ **OR** $140 \rightarrow 70 \rightarrow 35$ [1]

$\therefore\ n = 2$ [1]

The age of the wood $= 2 \times 5700 = 11400$ years [1]

17. (a) $^{238}_{94}\text{Pu} \rightarrow {}^{234}_{92}\text{Y} + {}^{4}_{2}\text{He}$ (OR $^{4}_{2}\alpha$) [2]

(b) (i) The tracks are straight. [1]
OR
The tracks are thick. [1]

(ii) As α radiation has weak penetrating power, [1]
they are stopped by the paper. [1]

(c) 2 W → 1 W → 0.5 W → 0.25 W [1]
OR
$\dfrac{0.25}{2} = \left(\dfrac{1}{2}\right)^n \quad \therefore n = 3$ [1]

Hence, the heater can last 3 half-lives. [1]

Time $= 3 \times 87.7 = 263.1$ years < accept 263 years > [1]

18. (a) (i) α particle [1]

(ii) β particle [1]

(b) $k = \dfrac{\ln 2}{7.1\times10^8} = 9.76\times10^{-10}$ year^{-1} [1]

$\dfrac{N}{N_o} = e^{-kt} = e^{-(9.76\times10^{-10})\times(10^8)} = 0.907$ [1]

$\therefore$ percentage left = 90.7% [1]

OR

$\dfrac{N}{N_o} = \left(\dfrac{1}{2}\right)^{t/t_{1/2}}$ [1]

$= \left(\dfrac{1}{2}\right)^{(10^8)/(7.1\times10^8)} = 0.907$ [1]

$\therefore$ percentage left = 90.7% [1]

19. (a) (i) $k = \dfrac{\ln 2}{1.3\times10^9}$ **OR** $\dfrac{\ln 2}{1.3\times10^9\times365\times24\times3600}$ [1]

$= 5.33\times10^{-10}$ year^{-1} **OR** 1.69×10^{-17} s^{-1} [1]

(ii) The decay constant of a radioactive isotope is the probability of decay of the nuclei present [1]
per unit time. [1]

(b) $\because$ $A = A_o e^{-kt}$

$\therefore$ $(1.6) = (4.8)\, e^{-5.33\times10^{-10}t}$ **OR** $(1.6) = (4.8)\, e^{-1.69\times10^{-17}t}$ [1]

$\therefore$ $t = 2.06\times10^9$ years **OR** $t = 6.50\times10^{16}$ s [1]

(c) ① The number of undecayed nuclei present [1]

② The decay constant of the radioactive source < **OR** The half-life of the radioactive source > [1]

20. (a) (i) $k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{(5730\times365\times24\times3600)}$ [1]

$= 3.84\times10^{-12}$ s^{-1} [1]

(ii) Number of carbon-14 atoms in 1 g of carbon :

$N = \dfrac{1}{12}\times6.02\times10^{23}\times\dfrac{1}{7.2\times10^{11}} = 6.97\times10^{10}$ [1]

$A = kN = (3.84\times10^{-12})\times(6.97\times10^{10})$ [1]

$= 0.268$ Bq < accept 0.267 Bq > [1]

20. (b) (i) Carbon-14 is formed when neutrons produced by cosmic rays collide with nitrogen.

$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}p$ [1]

Carbon-14 forms radioactive carbon dioxide and is taken up by plants for photosynthesis.
(**OR** Carbon-14 is taken up by animals through eating.) [1]

This exchange maintains the same abundance inside a living thing until it dies. [1]

(ii) Activity of the bone per gram : $A = \dfrac{2}{60} = 0.0333$ Bq [1]

By $A = A_o e^{-kt}$ $\therefore$ $(0.0333) = (0.268)\, e^{-(3.84\times10^{-12})t}$ [1]

$\therefore$ $t = 5.43\times10^{11}$ s = 17200 years [1]

OR

By $A = A_o\left(\dfrac{1}{2}\right)^{t/t_{1/2}}$ $\therefore$ $(0.0333) = (0.268)\left(\dfrac{1}{2}\right)^{t/5730}$ [1]

$\therefore$ $t = 17200$ years [1]

21. (a) $k = \dfrac{\ln 2}{5730\times3.16\times10^7} = 3.83\times10^{-12}$ s^{-1} [1]

By $A = kN$

$\therefore$ $(0.2) = (3.83\times10^{-12})\,N$ [1]

$\therefore$ $N = 5.22\times10^{10}$ [1]

(b) $N_o = (1\times10^{23})\times(1.3\times10^{-12}) = 1.3\times10^{11}$ [1]

(c) $N = N_o e^{-kt}$

$(5.22\times10^{10}) = (1.3\times10^{11})\, e^{-(3.83\times10^{-12})t}$ [1]

$\therefore$ $t = 2.38\times10^{11}$ s = 7540 years < accept 7500 to 7600 years > [1]

22. (a) $238 = 206 + 4\,n_\alpha$ $\therefore$ $n_\alpha = 8$ [1]

$92 = 82 + 8\times(2) + n_\beta\,(-1)$ $\therefore$ $n_\beta = 6$ [1]

(b) (i) $N = N_o\left(\dfrac{1}{2}\right)^{t/t_{1/2}}$ [**OR** $N = N_o e^{-kt}$ and $k = \dfrac{\ln 2}{t_{1/2}}$] [1]

$\therefore$ $\left(\dfrac{3}{5}\right) = \left(\dfrac{1}{2}\right)^{t/(4.5\times10^9)}$

$\therefore$ $t = 3.32\times10^9$ years < accept 3.3×10^9 years > [1]

22. (b) (ii) Answer in part (i) is underestimate. [1]

The original number of U-238 should be greater.

The ratio $\frac{\text{present number of U-235 atoms}}{\text{original number of U-238 atoms}}$ is in fact smaller than $\frac{3}{5}$ [1]

thus, longer time should have been elapsed.

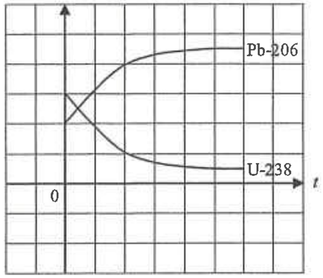
OR

Answer in part (i) is underestimate. [1]

Since more U-235 should have been decayed, [1]

thus longer time should have been elapsed.

(iii)



< Initial no. of Pb-206 is at 2 units as U : Pb = 3 : 2 initially > [1]

< Final no. of Pb is at 4.5 units since U + Pb = 5 and finally U has 0.5 unit > [1]

23. (a) $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$ < accept $^{4}_{2}\alpha$ > [2]

(b) The α particles ionize the air molecules. [1]

The ions neutralize the charges on the dust (**OR** film surface). [1]

(c) This is because α has a short range of a few centimetre in air. [1]

(d) $A = (1) \times \left(\frac{1}{2}\right)^{365/138}$ [1]

$= 0.160$ unit [1]

OR

$k = \frac{\ln 2}{(138)} = 0.005023$ [1]

$A = (1)\ e^{-(0.005023)(365)} = 0.160$ unit [1]

24. (a) (i) 226 − 206 = 20 which is a multiple of 4 (for α) [1]

∴ $^{206}_{82}\text{Pb}$ is the end product [1]

(ii) $\frac{N}{N_o} = \left(\frac{1}{2}\right)^{t/t_{1/2}} = \left(\frac{1}{2}\right)^{(50)/(1600)}$ [1]

$= 97.9\ \%$ < accept 98 % > [1]

OR

$k = \frac{\ln 2}{1600} = 4.33 \times 10^{-4}$

$\frac{N}{N_o} = e^{-kt} = e^{-(4.33\times10^{-4})\times(50)}$ [1]

$= 97.9\ \%$ < accept 98 % > [1]

(b) (i) Due to random nature of radiation [1]

(ii) Some of the daughter products of Ra-226 may emit β particles [1]

(iii) Since the ionizing power of β and γ are weaker than that of α [1]

Any **ONE** of the following : [1]

* Raise the source to a distance greater than the range of α, sparks will cease.
* Insert a paper between the source and the gauze, sparks will cease.

Hong Kong Diploma of Secondary Education Examination

Physics – Compulsory part (必修部分)

Section A – Heat and Gases (熱和氣體)
1. Temperature, Heat and Internal energy (溫度、熱和內能)
2. Transfer Processes (熱轉移過程)
3. Change of State (形態的改變)
4. General Gas Law (普適氣體定律)
5. Kinetic Theory (分子運動論)

Section B – Force and Motion (力和運動)
1. Position and Movement (位置和移動)
2. Newton's Laws (牛頓定律)
3. Moment of Force (力矩)
4. Work, Energy and Power (作功、能量和功率)
5. Momentum (動量)
6. Projectile Motion (拋體運動)
7. Circular Motion (圓周運動)
8. Gravitation (引力)

Section C – Wave Motion (波動)
1. Wave Propagation (波的推進)
2. Wave Phenomena (波動現象)
3. Reflection and Refraction of Light (光的反射及折射)
4. Lenses (透鏡)
5. Wave Nature of Light (光的波動特性)
6. Sound (聲音)

Section D – Electricity and Magnetism (電和磁)
1. Electrostatics (靜電學)
2. Electric Circuits (電路)
3. Domestic Electricity (家居用電)
4. Magnetic Field (磁場)
5. Electromagnetic Induction (電磁感應)
6. Alternating Current (交流電)

Section E – Radioactivity and Nuclear Energy (放射現象和核能)
1. Radiation and Radioactivity (輻射和放射現象)
2. Atomic Model (原子模型)
3. Nuclear Energy (核能)

Physics – Elective part (選修部分)

Elective 1 – Astronomy and Space Science (天文學和航天科學)
1. The universe seen in different scales (不同空間標度下的宇宙面貌)
2. Astronomy through history (天文學的發展史)
3. Orbital motions under gravity (重力下的軌道運動)
4. Stars and the universe (恆星和宇宙)

Elective 2 – Atomic World (原子世界)
1. Rutherford's atomic model (盧瑟福原子模型)
2. Photoelectric effect (光電效應)
3. Bohr's atomic model of hydrogen (玻爾的氫原子模型)
4. Particles or waves (粒子或波)
5. Probing into nano scale (窺探納米世界)

Elective 3 – Energy and Use of Energy (能量和能源的使用)
1. Electricity at home (家居用電)
2. Energy efficiency in building (建築的能源效率)
3. Energy efficiency in transportation (運輸業的能源效率)
4. Non-renewable energy sources (不可再生能源)
5. Renewable energy sources (可再生能源)

Elective 4 – Medical Physics (醫學物理學)
1. Making sense of the eye (眼的感官)
2. Making sense of the ear (耳的感官)
3. Medical imaging using non-ionizing radiation (非電離輻射醫學影像學)
4. Medical imaging using ionizing radiation (電離輻射醫學影像學)

DSE Physics - Section E : M.C. **PE - RA3 - M / 01**

RA3 : Nuclear Energy

Use the following data wherever necessary :

Atomic mass unit	$u = 1.661 \times 10^{-27}$ kg	(1 u is equivalent to 931 MeV)
Speed of light in vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}	
Charge of electron	$e = 1.6 \times 10^{-19}$ C	
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}	
Molar gas constant	$R = 8.31$ J mol^{-1} K^{-1}	

The following list of formulae may be found useful :

Law of radioactive decay	$N = N_0 e^{-kt}$
Half-life and decay constant	$t_{\frac{1}{2}} = \dfrac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$
Mass-energy relationship	$\Delta E = \Delta m c^2$

Part A : HKCE examination questions

1. **< HKCE 1983 Paper II - 37 >**

In the following nuclear reaction :

$${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{15}\text{P} + X$$

what is the mass number and atomic number of X ?

	Mass number	Atomic number
A.	1	0
B.	0	−1
C.	4	2
D.	0	0

2. **< HKCE 1986 Paper II - 40 >**

Which of the following equations represent(s) possible nuclear reactions ?

(1) ${}^{10}_{5}\text{B}$ + neutron $\longrightarrow$ ${}^{6}_{3}\text{Li}$ + α particle

(2) ${}^{210}_{83}\text{Bi}$ $\longrightarrow$ ${}^{210}_{84}\text{Po}$ + β particle

(3) ${}^{14}_{7}\text{N}$ + α particle $\longrightarrow$ ${}^{17}_{8}\text{O}$ + proton

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

3. < HKCE 1991 Paper II - 39 >

Which of the following equations represents(s) possible nuclear reaction(s) ?

(1) ${}^{27}_{13}Al + {}^{4}_{2}He \longrightarrow {}^{30}_{15}P$ + proton

(2) ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He$ + neutron

(3) ${}^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa$ + β particle

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

4. < HKCE 1993 Paper II - 41 >

$${}^{27}_{13}Al + {}^{4}_{2}He \longrightarrow {}^{30}_{15}P + X$$

In the above nuclear reaction, what are the atomic number and mass number of X ?

	Atomic number	Mass number
A.	−1	0
B.	−1	1
C.	0	1
D.	1	0

5. < HKCE 1996 Paper II - 37 >

In the below nuclear reactions, what do X, Y and Z represent ?

(1) ${}^{210}_{84}Po \longrightarrow {}^{206}_{82}Pb + X$

(2) ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + Y$

(3) ${}^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + Z$

	X	Y	Z
A.	an α particle	a proton	a β particle
B.	an α particle	a neutron	a β particle
C.	an α particle	a neutron	γ rays
D.	a β particle	a neutron	γ rays

6. < HKCE 2004 Paper II - 40 >

$${}^{2}_{1}H + {}^{x}_{1}H \rightarrow {}^{4}_{y}Z + \text{a neutron}$$

Find the values of x and y in the above nuclear reaction.

	x	y
A.	2	1
B.	2	2
C.	3	1
D.	3	2

7. < HKCE 2005 Paper II - 26 >

Which of the following nuclear reactions is a nuclear fusion ?

A. ${}^{235}_{92}U + n \longrightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + 2n$

B. ${}^{14}_{7}N + n \longrightarrow {}^{14}_{6}C + {}^{1}_{1}H$

C. ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + n$

D. ${}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + \alpha$

8. < HKCE 2008 Paper II - 26 >

Which of the following nuclear reactions is a fission ?

A. ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{144}_{56}BA + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n$

B. ${}^{238}_{92}U + {}^{1}_{0}n \longrightarrow {}^{239}_{94}Pu + 2\,{}^{0}_{-1}e$

C. ${}^{238}_{92}U + {}^{14}_{7}N \longrightarrow {}^{248}_{99}Es + 4\,{}^{1}_{0}n$

D. ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n$

9. < HKCE 2009 Paper II - 27 >

Which of the following conditions is/are necessary to sustain the chain reaction in the nuclear fission of uranium-235 ?

(1) Each fission produces a large amount of energy.
(2) At least one neutron is released in each fission.
(3) Each fission produces two smaller nuclei.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

10. < HKCE 2009 Paper II - 24 >

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + n$$

Which of the following descriptions about the nuclear reaction above is correct ?

A. It is a nuclear fission.
B. It is a nuclear fusion.
C. It is a chain reaction.
D. It is a radioactive decay.

Part B : HKAL examination questions

11. < HKAL 1980 Paper I - 49 >

Which of the following equations represent possible nuclear reactions ?

(1) ${}^{10}_{5}B$ + neutron $\longrightarrow {}^{6}_{3}Li + {}^{4}_{2}He$

(2) ${}^{210}_{83}Bi \longrightarrow {}^{210}_{84}Po$ + beta particle

(3) ${}^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O$ + proton

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

12. < HKAL 1992 Paper I - 48 >

$^{14}_{7}N$ + alpha particle $\longrightarrow$ proton + X

In the above nuclear reaction, X represents

A. $^{17}_{8}O$
B. $^{17}_{9}F$
C. $^{17}_{7}N$
D. $^{11}_{6}C$

13. < HKAL 1992 Paper I - 44 >

The main reason why a chain reaction can occur in a nuclear reactor using uranium-235 is that

A. a large quantity of energy is evolved in each fission.
B. the products of nuclear fission are highly radioactive.
C. plutonium is produced and it undergoes further fission.
D. more than 1 neutron is produced when a nucleus undergoes fission.

14. < HKAL 2003 Paper IIA - 43 >

The sun and stars give out their power mainly by

(1) radioactive decay.
(2) nuclear fission.
(3) nuclear fusion.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

15. < HKAL 2004 Paper IIA - 44 >

Two deuterons, $^{2}_{1}H$, combine together form a helium isotope, $^{3}_{2}He$, with the release of energy as shown below.

$$2\,^{2}_{1}H \rightarrow \,^{3}_{2}He + X + \text{energy}$$

Which of the following statements are correct ?

(1) This is an example of nuclear fusion.
(2) The total mass of $^{3}_{2}He$ and X is greater than that of the two $^{2}_{1}H$.
(3) X is a neutron.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

16. < HKAL 2005 Paper IIA - 22 >

The following equation represents a nuclear fission reaction of U-235, producing q neutrons.

$$^{235}_{92}U + \,^{1}_{0}n \longrightarrow \,^{141}_{56}Ba + \,^{92}_{Z}Kr + q\,^{1}_{0}n$$

What are the values of the atomic number Z and the number q ?

	Z	q
A.	37	2
B.	36	2
C.	36	3
D.	34	3

17. < HKAL 2012 Paper IIA - 45 >

Which of the following nuclear reactions are accompanied with a mass defect ?

(1) the union of hydrogen isotopes to form helium

$$^{2}_{1}H + \,^{3}_{1}H \longrightarrow \,^{4}_{2}He + \,^{1}_{0}n$$

(2) the natural radioactive decay of radium-226

$$^{226}_{88}Ra \longrightarrow \,^{222}_{86}Rn + \,^{4}_{2}He$$

(3) the emission of a β-particle from a nucleus

$$^{1}_{0}n \longrightarrow \,^{1}_{1}H + \,^{0}_{-1}e$$

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

18. < HKAL 2013 Paper IIA - 44 >

The sun radiates energy at a constant rate of 4.0×10^{26} W by a nuclear fusion process. The mass of the sun is 2.0×10^{30} kg. Estimate the lifetime of the sun if 0.07% of its mass is converted into radiation energy during the sun's lifetime.

Given : 1 year = 3.15×10^{7} s

A. 1.0×10^{6} years
B. 1.0×10^{10} years
C. 1.0×10^{12} years
D. 1.0×10^{17} years

Part C : Supplemental exercise

19. In which type of nuclear reaction are the daughter nuclei heavier than the mother nuclei ?

A. α-decay
B. β-decay
C. γ-emission
D. nuclear fusion

20. A worker at a nuclear plant walks into a room and is accidentally exposed to a small amount of radiation. The worker will

A. lose consciousness.
B. feel very hot.
C. feel painful.
D. feel no effect.

21. In the Sun, energy is released when hydrogen nuclei collide and form heavier nuclei. This process is called

A. diffusion.
B. fission.
C. fusion.
D. ionization.

22. In a particular chain reaction, a neutron collides with a heavy nucleus. The nucleus then splits to give two lighter nuclei, energy and

A. alpha particles.
B. beta particles.
C. protons.
D. neutrons.

23. Which of the following show(s) nuclear fission ?

(1) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$

(2) $^{241}_{94}Pu \longrightarrow ^{237}_{92}U + ^{4}_{2}He$

(3) $^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

24. A U-235 nucleus will split when it captures

A. an alpha particle.
B. a beta particle.
C. a neutron.
D. a proton.

25. The Sun releases its energy mainly by

(1) radioactive decay.
(2) nuclear fission.
(3) nuclear fusion.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

26. The following equations represent some typical nuclear reactions :

(I) $^{9}_{4}Be + ^{1}_{1}H \longrightarrow ^{6}_{3}Li + ^{4}_{2}He$

(II) $^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$

(III) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{148}_{57}La + ^{85}_{35}Br + 3\,^{1}_{0}n$

Which of the following descriptions of these reactions is/are correct ?

(1) Reaction (I) represents an α-decay.
(2) Reaction (II) represents a nuclear fusion.
(3) Reaction (III) represents a nuclear fission.

A. (1) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

27. The main reason why a chain reaction can occur in a nuclear reactor using uranium is that

A. a large amount of energy is released in each fission.
B. the products of nuclear fission are highly radioactive.
C. uranium splits into two smaller fragments.
D. fission neutrons are produced

28. If there were accident in a nearby nuclear power plant, which of the following is NOT the way that the radioactive substances released in the accident can spread to the neighbouring lands ?

A. By wind
B. By rain water
C. By animals
D. By plants

29. Which of the following is NOT the disadvantage of using nuclear energy ?

A. The capital investment of a nuclear power plant is very large.
B. There must be leakage of radiation in a nuclear power plant.
C. Once accident occurs, it would be very serious.
D. The disposal of radioactive waste is a difficult problem.

30. Which of the following do(es) NOT make use of nuclear fusion ?

(1) A nuclear bomb
(2) A hydrogen bomb
(3) Emission of light by a star

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

31. Which of the followings are the advantages of using nuclear energy ?

(1) Nuclear energy causes less pollution to our environment.
(2) The running cost of power plant using nuclear energy is lower.
(3) Nuclear energy is the only choice other than the use of fossil fuel.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

32. Which of the following are the advantages of using nuclear fusion to generate electricity ?

(1) The fuel for nuclear fusion is hydrogen which has unlimited supply in oceans.
(2) The waste products in nuclear fusion are not radioactive.
(3) The nuclear fusion takes place at a very high temperature.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

33. Which of the following are the difficulties to use nuclear fusion for generating electricity ?

(1) Nuclear fusion can only take place at a very high temperature.

(2) No physical container can withstand the high temperature that fusion occurs.

(3) It is difficult to dispose the waste products of the fusion.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

34. Which of the following nuclear reactions is/are an example of fusion ?

(1) $^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{N} + {}^{4}_{2}\text{He} + \text{energy}$

(2) $^{14}_{6}\text{C} \longrightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e} + \text{energy}$

(3) $^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \longrightarrow {}^{3}_{2}\text{He} + {}^{1}_{0}\text{n} + \text{energy}$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

35. Which of the following nuclear reactions is an example of fusion ?

A. Carbon-14 decaying to nitrogen and an electron

B. Two heavy hydrogen nuclei becoming helium and a neutron

C. Radium-226 decaying to radon-222 and an alpha particle

D. Sodium-24 decaying to magnesium-24 and a beta particle

36. In the following nuclear decay :

$$^{24}_{11}\text{Na} \longrightarrow {}^{24}_{12}\text{Mg} + {}^{0}_{-1}\beta$$

Given the data below :

mass of $^{24}_{11}$Na = 23.99096 u

mass of $^{24}_{12}$Mg = 23.98504 u

energy released in the decay = 5.00216 MeV

Calculate the rest mass of the beta particle released.

A. 0.00025 u
B. 0.00055 u
C. 0.00085 u
D. 0.00952 u

37. A star releases energy by nuclear fusion continuously. The mass of the star decreases by 2×10^{16} kg in one year. Calculate the average power released by the star.

A. 5.7×10^{25} W

B. 6.9×10^{25} W

C. 7.2×10^{25} W

D. 8.6×10^{25} W

Part D : HKDSE examination questions

38. **< HKDSE Sample Paper IA - 34 >**

Which of these is a nuclear fusion reaction ?

A. $^{235}_{92}\text{U} + \text{n} \longrightarrow {}^{144}_{56}\text{Ba} + {}^{90}_{36}\text{Kr} + 2\,\text{n}$

B. $^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + \text{n}$

C. $^{14}_{7}\text{N} + \text{n} \longrightarrow {}^{14}_{6}\text{C} + {}^{1}_{1}\text{H}$

D. $^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + \alpha$

39. **< HKDSE Practice Paper IA - 36 >**

For the following nuclear reaction, state the type of reaction and determine the energy released.

$$^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$$

Given : mass of $^{2}_{1}$H = 2.014 u

mass of $^{3}_{1}$H = 3.016 u

mass of $^{4}_{2}$He = 4.003 u

mass of $^{1}_{0}$n = 1.009 u

	Type of reaction	Energy released
A.	fusion	0.018 MeV
B.	fusion	16.76 MeV
C.	fission	0.018 MeV
D.	fission	16.76 MeV

40. **< HKDSE 2013 Paper IA - 36 >**

The sun releases huge amount of energy through thermonuclear fusion while at the same time its mass decreases. The average power released by the sun is about 3.8×10^{26} W. Estimate the decrease in mass of the sun in one second.

A. 4.2×10^{6} kg

B. 4.2×10^{9} kg

C. 1.3×10^{15} kg

D. 1.3×10^{18} kg

41. **< HKDSE 2014 Paper IA - 33 >**

A radium nucleus decays to a radon nucleus by emitting an α-particle. The energy released in the process is 4.9 MeV. Compared to the mass of a radium nucleus, the total mass of a radon nucleus and an α-particle is

A. 5.4×10^{-11} kg less.

B. 5.4×10^{-11} kg more.

C. 8.7×10^{-30} kg less.

D. 8.7×10^{-30} kg more.

42. < HKDSE 2015 Paper IA - 31 >

Which of the following nuclear reactions is/are spontaneous reaction(s) ?

(1) ${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} + {}^{0}_{-1}\text{e}$

(2) ${}^{10}_{5}\text{B} + {}^{1}_{0}\text{n} \rightarrow {}^{7}_{3}\text{Li} + {}^{4}_{2}\text{He}$

(3) ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

43. < HKDSE 2017 Paper IA - 33 >

The following shows the decay of uranium-238 (${}^{238}_{92}\text{U}$).

$${}^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$$

Given that : mass of ${}^{238}_{92}\text{U}$ = 238.05079 u
mass of ${}^{234}_{90}\text{Th}$ = 234.04363 u
mass of ${}^{4}_{2}\text{He}$ = 4.00260 u

Which of the following statements is/are correct ?

(1) The temperature required to start the decay is about 10^7 K.
(2) The energy released in the decay of one uranium-238 nucleus is 4.25 MeV.
(3) All the energy released in the decay becomes the kinetic energy of ${}^{4}_{2}\text{He}$.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

44. < HKDSE 2018 Paper IA - 31 >

Which of the following nuclear reactions is/are possible for a chain reaction to occur ?

(1) ${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \longrightarrow {}^{1}_{0}\text{n} + {}^{4}_{2}\text{He}$

(2) ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3\,{}^{1}_{0}\text{n}$

(3) ${}^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \longrightarrow {}^{148}_{58}\text{Ce} + {}^{89}_{36}\text{Kr} + 3\,{}^{1}_{0}\text{n}$

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

45. < HKDSE 2018 Paper IA - 33 >

Given: mass of proton = 1.007276 u
mass of neutron = 1.008665 u
mass of ${}^{3}_{2}\text{He}$ nucleus = 3.016030 u

When a ${}^{3}_{2}\text{He}$ nucleus is formed from 2 protons and 1 neutron,

A. 6.7 MeV energy is released.
B. 6.7 MeV energy is required.
C. 8.0 MeV energy is released.
D. 8.0 MeV energy is required.

There is question in next page

HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

M.C. Answers

1. A	11. D	21. C	31. A	41. C
2. D	12. A	22. D	32. A	42. A
3. D	13. D	23. A	33. A	43. B
4. C	14. B	24. C	34. B	44. D
5. B	15. B	25. B	35. B	45. A
6. D	16. C	26. C	36. B	**46. C**
7. C	17. D	27. D	37. A	
8. A	18. B	28. D	38. B	
9. B	19. D	29. B	39. B	
10. B	20. D	30. A	40. B	

M.C. Solution

1. A

$${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{15}\text{P} + {}^{1}_{0}X$$

Mass number = 1
Atomic number = 0

2. D

×	(1)	${}^{10}_{5}\text{B} + {}^{1}_{0}n \rightarrow {}^{6}_{3}\text{Li} + {}^{4}_{2}\text{He}$	Mass number is not balanced.
✓	(2)	${}^{210}_{83}\text{Bi} \rightarrow {}^{210}_{84}\text{Po} + {}^{0}_{-1}e$	Both mass number and atomic number are balanced.
✓	(3)	${}^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \rightarrow {}^{17}_{8}\text{O} + {}^{1}_{1}p$	Both mass number and atomic number are balanced.

3. D

×	(1)	${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{15}\text{P} + {}^{1}_{1}p$	Atomic number is not balanced.
✓	(2)	${}^{2}_{1}\text{H} + {}^{3}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}n$	Both mass number and atomic number are balanced.
✓	(3)	${}^{231}_{90}\text{Th} \rightarrow {}^{231}_{91}\text{Pa} + {}^{0}_{-1}e$	Both mass number and atomic number are balanced.

4. C

Balancing the equation, ${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \rightarrow {}^{30}_{15}\text{P} + {}^{1}_{0}X$

Atomic number = 0
Mass number = 1

5. B

(1) $^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}He$ X: α particle

(2) $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$ Y: neutron

(3) $^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$ Z: β particle

6. D

The symbol of neutron is $^{1}_{0}n$

Balance the mass number : $2 + x = 4 + 1$ $\therefore x = 3$

Balance the atomic number : $1 + 1 = y + 0$ $\therefore y = 2$

7. C

× A. This is an example of nuclear fission.

× B. This is an example of bombardment of particle into a nucleus.

✓ C. Fusion is the combination of two smaller nuclei : H-2 and H-3 to form a larger nucleus : He-4.

× D. This is an example of alpha decay.

8. A

✓ A. It is a typical fission of U-235, triggered by a neutron.

× B. It is a bombardment of particle reaction.

× C. It is a bombardment of particle reaction.

× D. It is a fusion.

9. B

× (1) Fission would produce a large amount of energy, but the energy cannot sustain the chain reaction.

✓ (2) In each fission, neutrons are produced and these neutrons can trigger the further fission of U-235, thus the chain reaction can be sustained.

× (3) Fission produces two smaller nuclei, but these smaller nuclei cannot sustain the further fission.

10. B

As the reaction involves the combination of H-2 and H-3 to become He-4, it is a fusion reaction.

11. D

× (1) $^{10}_{5}B + ^{1}_{0}n \rightarrow ^{6}_{3}Li + ^{4}_{2}He$ Mass number is not conserved.

✓ (2) $^{210}_{83}Bi \rightarrow ^{210}_{84}Po + ^{0}_{-1}e$ Both mass number and charge are conserved.

✓ (3) $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}p$ Both mass number and charge are conserved.

12. A

Balancing the mass number and atomic number : $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{1}_{1}p + ^{17}_{8}O$.

13. D

Neutrons can trigger the further fissions of the remaining U-235 nuclei, thus maintain the chain reaction

14. B

× (1) The energy released in decay is negligible compared with that in nuclear fission or fusion.

× (2) Nuclear fission occurs for element of very high atomic number. The sun and stars do not contain these elements.

✓ (3) The sun and stars contain mainly hydrogen and helium for nuclear fusion to take place.

15. B

✓ (1) Small nuclei $^{2}_{1}H$ combining to form large nuclei $^{3}_{2}He$ is a fusion process.

× (2) Since energy is released, there must be mass defect. Thus the total mass of the product should be smaller.

✓ (3) $2\,^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}X$ $\therefore$ X is a neutron.

16. C

① $235 + 1 = 141 + 92 + q$

② $92 + 0 = 56 + z + 0$

$\therefore z = 36$ and $q = 3$

17. D

✓ (1) Since energy is released in this nuclear fusion, thus there is mass defect.

✓ (2) Since energy is released and becomes the kinetic energy of α-particle, there is mass defect.

✓ (3) Since energy is released and becomes the kinetic energy of β-particle, there is mass defect.

18. B

$E = mc^2 = (2.0 \times 10^{30} \times 0.07\%) \times (3 \times 10^8)^2 = 1.26 \times 10^{44}$ J

$E = Pt$

$\therefore (1.26 \times 10^{44}) = (4.0 \times 10^{26})\,t$ $\therefore t = 3.15 \times 10^{17}$ s $= 1 \times 10^{10}$ years

19. D

× A. After α-decay, the daughter nucleus has its mass number decreased by 4.

× B. After β-decay, the daughter nucleus has its mass slightly decreased due to mass defect.

× C. After γ-emission, the mass of the nucleus is slightly decreased due to mass defect.

✓ D. After nuclear fusion, the nucleus is heavier since it consists of smaller nuclei combining together.

20. D

There is no immediate effect on a worker who is exposed to small amount of radiation.

However, the radiation is accumulative in the human body and thus increases the chance of cancer in the future.

21. C

The Sun makes use of nuclear fusion to give out solar energy.

22. D

After nuclear fission, 2, 3 or 4 fission neutrons may be produced to cause further fission, thus give the chain reaction.

23. A

✓ (1) It is a typical fission of U-235.

× (2) It is an α-decay.

× (3) It is fusion.

24. C

When a neutron is captured by a U-235 nucleus, the neutron will trigger the fission of the uranium nucleus.

25. B

× (1) The Sun does not contain radioactive nuclei to give radioactive decay.

× (2) The Sun does not contain large nuclei to give fission.

✓ (3) The Sun contains mainly hydrogen that undergoes fusion to give out solar energy.

26. C

× (1) Reaction (I) is the bombardment of proton on the Be-9 nucleus to give two other nuclei.

✓ (2) The combination of two smaller nuclei to give a large nucleus is called fusion.

✓ (3) The split up of a large nucleus to give two smaller nuclei is called fission.

27. D

The fission neutrons can trigger further fissions of the remaining uranium nuclei to give the chain reaction.

28. D

✓ A. Wind can carry the radioactive waste from one place to another place.

✓ B. Rain water can carry the radioactive waste from one place to flow to another place.

✓ C. Animals can bring the radioactive waste and move to another place.

× D. Since plants cannot move, they cannot carry radioactive waste from one place to another place.

29. B

✓ A. Building a nuclear power plant is very expensive to ensure every safety measure.

× B. A good design of nuclear power plant ensures no leakage of radiation to the environment.

✓ C. If explosion occurs in a nuclear power plant, it would cause disastrous effect to the environment.

✓ D. Since the wastes of fission product are radioactive, their disposal causes a series problem.

30. A

✓ (1) A nuclear bomb makes use of nuclear fission, NOT nuclear fusion.

× (2) A hydrogen bomb indeed makes use of nuclear fusion of hydrogen to give out energy.

× (3) A star, likes the Sun, makes use of nuclear fusion to give out energy.

31. A

✓ (1) Nuclear energy makes use of fission does not produce air pollution.

✓ (2) Nuclear energy is cheaper once the chain reaction starts.

× (3) Other than the fossil fuels, there are renewable energy resources such as solar energy, wind energy and hydroelectric energy.

32. A

✓ (1) In ocean, there is unlimited supply of water that consists of hydrogen.

✓ (2) The water products in nuclear fusion are helium which are noble gas and not radioactive.

× (3) Fusion takes place at high temperature is a disadvantage, not advantage.

33. A

✓ (1) Nuclear fusion takes place at very high temperature; it is not easy to produce such a high temperature.

✓ (2) Even the high temperature (about 10 000 000°C) is achieved, all containers will change to gases.

× (3) The waste products of fusion is clean and not radioactive, and thus no disposal problem.

34. B

× (1) It is an example of α-decay.

× (2) It is an example of β-decay.

✓ (3) It is an example of nuclear fusion.

35. B

Fusion is combining two smaller nuclei (hydrogen nuclei) to form a large nucleus (the helium).

36. B

As 1 u is equivalent to 931 MeV,

mass equivalent of the energy released $= \dfrac{5.00216}{931} = 0.00537$ u

By conservation of mass and energy,

$23.99096 = 23.98504 + m_\beta + 0.005373$

$\therefore\ m_\beta = 0.00055$ u

37. A

By $\Delta E = \Delta m c^2$

$\therefore \Delta E = (2 \times 10^{16}) \times (3 \times 10^8)^2 = 1.8 \times 10^{33}$ J

Assume 365 days in 1 year.

Average power : $P = \frac{E}{t} = \frac{1.8 \times 10^{33}}{365 \times 24 \times 3600} = 5.7 \times 10^{25}$ W

38. B

× A. This is an example of nuclear fission.
✓ B. Fusion is the combination of two smaller nuclei : H-2 and H-3 to form a larger nucleus : He-4.
× C. This is an example of bombardment of particle into a nucleus.
× D. This is an example of alpha decay.

39. B

Since the reaction is to combine two hydrogen nuclei into a helium nucleus, it is a fusion reaction.

Mass defect = 2.014 + 3.016 − 4.003 − 1.009 = 0.018 u

Energy released = 0018 × 931 = 16.76 MeV

40. B

In 1 second, energy released is 3.8×10^{26} J.

By $\Delta E = \Delta m c^2$

$\therefore (3.8 \times 10^{26}) = \Delta m (3 \times 10^8)^2 \quad \therefore \Delta m = 4.2 \times 10^9$ kg

41. C

By Einstein's equation :

$\Delta E = \Delta m c^2$

$\therefore (4.9 \times 10^6 \times 1.6 \times 10^{-19}) = \Delta m \times (3 \times 10^8)^2 \qquad \therefore \Delta m = 8.7 \times 10^{-30}$ kg

Since energy is released, there is mass defect.

Thus, the total mass of the daughter nucleus Y and α-particle is less than the mother nucleus.

42. A

✓ (1) This is a beta-decay reaction, which is spontaneous.
× (2) This is a bombardment reaction, triggered by the hitting of neutron onto the nucleus B-10.
× (3) This is a fusion reaction, which occurs when the temperature is high enough.

43. B

× (1) The decay is spontaneous, can take place in any temperature.
✓ (2) Mass defect : Δm = 238.05079 − 234.04363 − 4.00260 = 0.00456 u
Energy released : E = 0.00456 × 931 = 4.25 MeV
× (3) The energy released in the decay will become the kinetic energy of both Th and He.

44. D

× (1) Chain reaction only occurs in nuclear fission. This is a nuclear fusion, chain reaction does not occur.
✓ (2) There are 3 fission neutrons that can trigger the remaining U-235 to give chain reaction.
✓ (3) There are 3 fission neutrons that can trigger the remaining Pu-239 to give chain reaction.

45. A

Mass defect = 1.007276 × 2 + 1.008665 − 3.016030 = 0.007187 u

Energy released = 0.007187 × 931 = 6.7 MeV

Use the following data wherever necessary :

Speed of light in vacuum	$c = 3 \times 10^{8}$ m s^{-1}	
Charge of an electron	$e = 1.60 \times 10^{-19}$ C	
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}	
Atomic mass unit	u = 1.661×10^{-27} kg	(1 u is equivalent to 931 MeV)

The following list of formulae may be found useful :

Half-life and decay constant	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$
Activity and the number of undecayed nuclei	$A = kN$
Mass-energy relationship	$\Delta E = \Delta m\, c^2$

Part A : HKCE examination questions

1. **< HKCE 2003 Paper I - 9 >**

In 1986, a disastrous nuclear accident happened at the Chernobyl Nuclear Station. A large amount of radioactive substance was released and spread to neighbouring countries. The radiation levels recorded in these countries were much higher than the normal background count rate.

(a) State **two** sources of background radiation. (2 marks)

(b) State one way by which the radioactive substances released in the accident were spread to neighbouring countries. (1 mark)

(c) One of the radioactive isotopes released in the accident was caesium-137 (Cs-137). The following equation shows how Cs-137 is produced :

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \longrightarrow {}^{137}_{x}\text{Cs} + {}^{y}_{37}\text{Rb} + z\,{}^{1}_{0}\text{n}$$

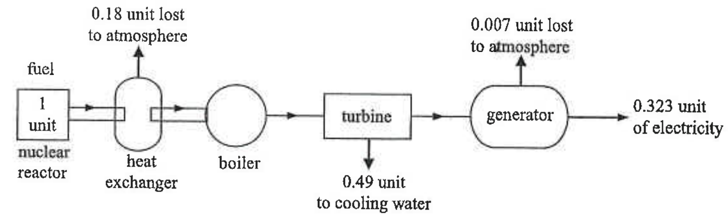
(i) If $z = 4$, find the values of x and y and state their physical meanings. (4 marks)

(ii) The half-life of Cs-137 is 30 years. Suppose that a soil sample contaminated by Cs-137 is 30 years was found to have an initial activity of 1.2×10^{6} Bq (disintegrations per second). A physicist comments that the contaminated sample will affect the environment for more than 300 years. Justify the physicist's claim with calculations. You may assume that the activity of a non-contaminated sample of similar nature is 200 Bq. (3 marks)

1. (d) The development of nuclear energy is a controversial issue. Do you support the development of nuclear energy ? State the reasoning to support your point of view. (4 marks)

Part B : HKAL examination questions

2. **< HKAL 1983 Paper IIB - 7 >**



In a nuclear reactor using U-235 as fuel, 1 unit of fission energy produced would undergo the changes shown in the above figure, that finally 0.323 unit of electrical energy is obtained.

(a) Suppose the electrical power output of this plant is 1066 MW.

(i) Calculate the total power generated by the reactor. (1 mark)

(ii) Find the total power lost to the atmosphere. (1 mark)

(b) The turbine is cooled by circulating water through it at the rate of 48 m^3 s^{-1}. Calculate the rise in temperature of the cooling water. (Density of water = 10^3 kg m^{-3}, specific heat capacity of water = 4200 J kg^{-1} K^{-1}) (3 marks)

(c) In the reactor, energy is produced by the fission of uranium-235 atoms.

$$^{235}\text{U} + \text{n} \longrightarrow {}^{141}\text{Ba} + {}^{92}\text{Kr} + 3\,\text{n}$$

Given : ^{235}U = 235.0409 u ; ^{141}Ba = 140.9141u ; ^{92}Kr = 91.9250 u ; n = 1.0086 u.

Calculate the number of uranium atoms which undergo fission in 1 s. (3 marks)

(d) The nuclear plant is designed to produce power continuously for 10 years without refuelling. Estimate the mass of uranium-235 required. Given that the molar mass of U-235 is 235 g. (2 marks)

3. < HKAL 1993 Paper IIB - 12 >

The following equation represents one of the nuclear reaction in a fission reactor :

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{91}_{36}Kr + ^{142}_{56}Ba + 3\,^{1}_{0}n$$

Given : the mass of one nucleus of $^{235}_{92}U$ = 235.0439 u

$^{91}_{36}Kr$ = 90.9234 u

$^{142}_{56}Ba$ = 141.9164 u

$^{1}_{0}n$ = 1.0087 u

(a) According to the above equation, find the mass defect between the reactants and products when one $^{235}_{92}U$ nucleus undergoes fission. (2 marks)

(b) If 4.00×10^{-5} kg of $^{235}_{92}U$ undergoes fission in one second, calculate the rate of energy production. Take the mass of one mole of $^{235}_{92}U$ as 235 g. (3 marks)

4. < HKAL 1998 Paper IIB - 5 >

A reaction which takes place in a nuclear reactor is shown by the following equation :

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,^{1}_{0}n + 173.8 \text{ MeV}$$

Mass of one nuclide of $^{235}_{92}U$ = 235.0439 u

Mass of one nuclide of $^{142}_{56}Ba$ = 141.9164 u

Mass of one nuclide of $^{91}_{36}Kr$ = 90.9234 u

(a) Calculate the mass of a neutron, express the answer in atomic mass unit. (3 marks)

(b) The fuel in the reactor contain 1.0×10^{4} kg of U-235. Calculate the total energy released when all the U-235 nuclei in the fuel have undergone fission. Take the mass of one mole of U-235 as 235 g. (3 marks)

(c) If the average power output of the reactor is 500 MW and the efficiency of conversion of nuclear energy to electrical energy is 40%, estimate the time for which the fuel can be used. (2 marks)

5. < HKAL 2002 Paper I - 7 >

The energy released by the Sun is the result of nuclear fusion in its core, where hydrogen are fused together into helium nuclei through a complicated process. The overall reaction can be simplified by the following equation :

$$4\,^{1}_{1}H \longrightarrow ^{4}_{2}He + \text{other particles of negligible mass} + \text{energy}$$

(a) Why is the above process of forming helium nuclei from protons very difficult to achieve on Earth, but easily achieved at the Sun's core ? (2 marks)

(b) Given : mass of hydrogen = 1.00728 u

mass of helium = 4.00150 u

Calculate the energy released in each fusion by the Sun. Express your answer in joule. (2 marks)

(c) Calculate the total energy released by the Sun for every kilogram of hydrogen fused to form helium nuclei. Take the mass of one mole of hydrogen ($^{1}_{1}H$) be 1 g. (2 marks)

6. < HKAL 2010 Paper I - 4 >

A nucleus of radon ($^{222}_{86}Rn$) decays to an isotope of polonium (Po) by emitting an α-particle.

Given : mass of a radon nucleus = 222.0176 u

mass of a polonium nucleus = 218.0090 u

mass of an α-particle = 4.0026 u

(a) Write an equation for the decay and find the energy released, in MeV, in the decay. (3 marks)

(b) The energy released in the decay becomes the kinetic energy of the decay products. Explain quantitatively why the α-particle takes most of the decay energy. Assume that the parent nucleus is at rest initially. (2 marks)

(c) Hence calculate the speed v of the α-particle, assume all the decay energy is transferred to the α-particle. (2 marks)

7. < HKAL 2012 Paper I - 6 >

Iodine-131 ($^{131}_{53}I$) is a common radioactive nuclide found in radioactive waste from nuclear power plants. It undergoes β decay and becomes a stable nuclide Xenon-131 (^{131}Xe) with a half-life of 8.02 days.

(a) Write down the decay equation of Iodine-131. (1 mark)

(b) (i) Estimate the initial activity of 1 kg of Iodine-131 in Bq. (3 marks)

Given : mass of one mole of Iodine-131 = 131 g

(ii) Assuming that all the decay energy of Iodine-131 becomes heat, find the initial heating power of 1 kg of Iodine-131 in the unit W. (4 marks)

Given : mass of an Iodine-131 nucleus = 130.90612 u

mass of a Xenon-131 nucleus = 130.90508 u

mass of an electron = 0.00054 u

(c) Even after a reactor is shut down and nuclear fission is completely stopped, fission products like Iodine-131 keep on producing heat. Explain why we cannot stop the Iodine-131 from producing heat. (2 marks)

(d) Iodine-123 is another radioactive isotope of Iodine. It emits γ rays and has a half-life of 13 hours. As thyroid in the human body readily absorbs iodine, Iodine-123 is commonly used as a medical tracer for diagnosis of thyroid diseases. Give ONE reason why Iodine-123 is more suitable to be used as medical tracer than Iodine-131. (1 mark)

Part C : Supplemental exercise

8. (a) When an alpha particle strikes a beryllium $\left(^{9}_{4}Be\right)$ nucleus, one carbon $\left(^{12}_{6}C\right)$ nucleus and one particle Q are formed. Write down the nuclear equation. What is the particle Q ? (3 marks)

(b) A nuclear power plant makes use of nuclear fission of uranium to generate electrical power at a rate of 500 MW. The internal energy that can be extracted from 1 kg of uranium fuel in the fission reactor is about 5.6×10^{12} J. The efficiency of energy conversion to electrical form in the nuclear reactor is only 30%. (1 MW = 10^6 W)

(i) What is the electrical energy supplied in one day ? (2 marks)

(ii) If electrical energy costs $0.9 for 1 kWh, how much does it cost for the electrical energy generated in one day ? (4 marks)

(iii) Calculate the electrical energy that can be produced by 1 kg of uranium in the fuel rod. (2 marks)

(iv) Find the mass of uranium fuel used in one day. (2 marks)

(c) Some people propose that nuclear energy should eventually replace oil and coal as sources of energy supply. Do you agree with this ? List 3 reasons to support your argument. (4 marks)

9. In a nuclear reactor for generating electricity, Uranium-235 undergoes fission to generate energy.

(a) Describe the process of nuclear fission of Uraniuim-235. (3 marks)

(b) The waste products from a nuclear reactor contain isotopes which are radioactive and emit β radiation. They are stored in sealed metal cans for 200 years until the activity decreases to 400 Bq that can be disposed of.

(i) Explain how these isotopes are produced. (2 marks)

(ii) What is meant by the term radioactive ? (2 marks)

(iii) State the reasons why metal cans are used to store the waste products. (1 mark)

(iv) It is known that the half life of the radioactive isotope in the metal cans is 25 years. What is the initial activity of the waste products in the cans ? (3 marks)

(v) Calculate the initial number of atoms of the radioactive isotope in the metal cans. (3 marks)

(c) David wonders why nuclear fusion is not used to generate electricity. Suggest two reasons to explain this. (2 marks)

Part D : HKDSE examination questions

10. **< HKDSE Sample Paper IB - 14 >**

In April 1986, a disastrous nuclear accident happened at the Chernobyl Nuclear Power Station. A large quantity of various radioactive substances was released and spread to neighbouring countries. The radiation levels recorded in these countries were much higher than the normal background radiation count rate.

(a) State ONE source of background radiation.

(b) One of the radioactive isotopes released in the accident was caesium-137 (Cs-137). The following equation shows how Cs-137 is produced :

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{137}_{55}Cs + ^{95}_{37}Rb + x\,^{1}_{0}n$$

Given : mass of one nuclide of $^{235}_{92}U$ = 235.0439 u
$^{137}_{55}Cs$ = 136.9071u
$^{95}_{37}Rb$ = 94.9399 u
$^{1}_{0}n$ = 1.0087 u.

(i) What is the value of x ? (1 mark)

(ii) Find the energy release in the fission of one U-235 nuclide in MeV. (2 marks)

(iii) The half-life of Cs-137 is 30 years. A soil sample contaminated by Cs-137 has an activity of 1.2×10^6 Bq. A physicist comments that the contaminated sample will affect the environment for more than 350 years. Justify the physicist's claim with calculations. It is known that the activity of an uncontaminated soil sample is 200 Bq. (2 marks)

11. **< HKDSE 2012 Paper IB - 11 >**

Radium-226 ($^{226}_{88}Ra$) undergoes α-decay into radon (Rn).

(a) Write a nuclear equation for the decay. (2 marks)

11. (b) Given : mass of a radium nucleus = 226.0254 u
mass of a radon nucleus = 222.0176 u
mass of an α-particle = 4.0026 u

Calculate the energy released in the decay in MeV. (2 marks)

(c) 1 curie (Ci) is defined as the activity of 1 g of radium. The activity of a radium source used in laboratories is about 5 μCi. Estimate the number of radium atoms in this source and hence find its activity expressed in disintegrations per second. The half-life of radium-226 is 1600 years and take the mass of one mole of radium as 226 g.
(1 μCi = 1×10^{-6} Ci) (3 marks)

12. < **HKDSE 2015 Paper IB - 10** >

Scientists had been experimenting controlled fusion in a nuclear reactor in which deuterium ($^2_1$H) and tritium ($^3_1$H) undergo the following nuclear fusion :

$$^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n} + \text{energy released}$$

Given : mass of a deuterium nucleus = 2.014102 u
mass of a tritium nucleus = 3.016049 u
mass of a helium nucleus = 4.002602 u
mass of a neutron = 1.008665 u

(a) Calculate the energy released, in MeV, in the above nuclear fusion. (2 marks)

(b) In the nuclear reactor, deuterium and tritium exist as plasma, which is a mixture of ions at a very high temperature. To start the fusion reaction, the average kinetic energy of the ions in the plasma has to reach the minimum value of 0.2 MeV.

(i) Explain why a very high temperature is needed for nuclear fusion to occur. (2 marks)

(ii) Estimate the order of magnitude of the minimum temperature at which fusion of deuterium and tritium nuclei would be possible if the plasma can be regarded as an ideal gas. (2 marks)

There is question in next page

Question Solution

1. (a) Any **TWO** of the following : [2]
* Cosmic radiation from the space
* Radiation from rocks
* Radiation in air
* Radiation from food
* Radiation from our body

(b) Any **ONE** of the following : [1]
* by wind
* by rain
* by water in river
* by imported food

(c) (i) $x = 92 - 37 = 55$ [1]
$y = 235 + 1 - 137 - 4 = 95$ [1]
x is the atomic number of Cs [1]
y is the mass number of Rb [1]

(ii) Number of half-life in 300 years = 10 [1]
Activity after 10 half-lives = $(1.2 \times 10^6) \times (\frac{1}{2})^{10}$ = 1172 Bq [1]
After 300 years, the activity is still higher than that of non-contaminated sample, thus his claim is correct. [1]

OR

By $A = A_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$\therefore$ $(200) = (1.2 \times 10^6) \times (\frac{1}{2})^{t/30}$ [1]

$\therefore$ t = 377 years [1]

A time longer than 300 years is required for the activity to drop to safe level, thus his claim is correct. [1]

(d) I support the development of nuclear power since
it is cheaper as the running cost is lower, and [2]
it is clean since it does not produce air pollution and acid rain. [2]

OR

I do not support the development of nuclear power since
it is dangerous as once accident occurs, it would be very serious, and [2]
it is expensive as the capital investment is very high. [2]

< accept other reasonable answers >

13. <HKDSE 2019 Ppaper-IB-10>

(a) The equation below represents nuclear fission of uranium-235 (U-235).

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + x\,^{1}_{0}n + 200\text{ MeV}$$

(i) What is the value of x ? (1 mark)

....

(ii) State a necessary condition for chain reaction of fission to occur. (1 mark)

....

....

....

Scientists found evidence in Oklo, Africa that natural nuclear fission occurred two billion (2×10^9) years ago. The uranium mineral ore mined from Oklo at present is found to have 0.6% concentration by mass of U-235 (see the table below), which is much lower than usual.

(b) The table gives the information of U-235 and U-238 in a sample of uranium mineral ore found in Oklo. Given: half-life of U-235 = 7.04×10^8 years

	2×10^9 years ago	at present
U-235	m_0 kg	0.060 kg (i.e. 0.6% concentration by mass)
U-238	13.556 kg	9.940 kg (i.e. 99.4% concentration by mass)

*(i) Estimate the amount m_0 (in kg) of U-235 in the sample 2×10^9 years ago. (2 marks)

(ii) Hence determine whether natural nuclear fission of U-235 was possible 2×10^9 years ago. For fission of U-235 to happen, its concentration by mass in the uranium mineral ore has to be at least 3%. (1 mark)

There must be underground water in the vicinity of this uranium-rich mineral deposit for natural nuclear fission to be possible. Since water can slow down the fast neutrons from fission, these neutrons can easily be captured by U-235.

(c) In fact the chain reaction stopped even before the concentration by mass of U-235 dropped to 3%. Explain why this occurred. (2 marks)

14. < HKDSE 2020 Paper 1B -10>

Given: mass of proton = 1.0073 u
mass of α particle = 4.0015 u
mass of $^{14}_{7}N$ nucleus = 13.9993 u
mass of $^{17}_{8}O$ nucleus = 16.9947 u

When a stationary $^{14}_{7}N$ nucleus is bombarded by an α particle, the following nuclear reaction can be triggered with products $^{17}_{8}O$ and X fly off:

$$\alpha + ^{14}_{7}N \longrightarrow ^{17}_{8}O + X$$

(a) What is X? (1 mark)

....

*(b) Based on energy consideration, estimate the minimum kinetic energy, in MeV, of the α particle required for such a nuclear reaction to occur. (2 marks)

(c) However, when conservation of momentum is also taken into account, the α particle must possess a kinetic energy greater than that found in (b) to bring about such a reaction. Explain. (2 marks)

2. (a) (i) As 1 unit of nuclear power can only give 0.323 unit of electricity, the efficiency is 32.3%

Power generated by the reactor $= 1066 \div 32.3\%$

$= 3300$ MW [1]

(ii) Power lost to the atmosphere $= 3300 \times (0.18 + 0.007)$

$= 617$ MW [1]

(b) Power delivered to cooling water $= 3300 \times 0.49$

$= 1617$ MW [1]

In 1 s, volume of water circulating is 48 m^3

$\therefore$ mass = volume $\times$ density $= 48 \times 10^3$ kg

By $E = m\,c\,\Delta T$ and consider the time of 1 s.

$\therefore\ (1617 \times 10^6) = (48 \times 1000) \times (4200) \times \Delta T$ [1]

$\therefore\ \Delta T = 8$ K [1]

(c) Mass defect :

$\Delta m = (235.0409 + 1.0086) - (140.9141 + 91.9250 + 3 \times 1.0086)$

$= 0.1846$ u [1]

Energy released in each fission :

$E = 0.1846 \times 931 \times 10^6 \times 1.6 \times 10^{-19}$

$= 2.75 \times 10^{-11}$ J [1]

OR

$E = m\,c^2$

$= (0.1846 \times 1.661 \times 10^{-27}) \times (3 \times 10^8)^2$

$= 2.76 \times 10^{-11}$ J [1]

Number of uranium atoms undergoing fission in 1 s :

By $P = \dfrac{N}{t}E$

$\therefore\ (3300 \times 10^6) = \dfrac{N}{t} \times (2.75 \times 10^{-11})$

$\therefore\ \dfrac{N}{t} = 1.20 \times 10^{20}\ s^{-1}$ [1]

(d) Mass of U-235 needed in 1 s $= \dfrac{1.20 \times 10^{20}}{6.02 \times 10^{23}} \times 0.235$

$= 4.684 \times 10^{-5}$ kg [1]

Mass of U-235 needed in 10 years $= 4.684 \times 10^{-5} \times 10 \times 365 \times 24 \times 3600$

$= 1.48 \times 10^4$ kg [1]

3. (a) Mass defect $= (235.0439\ u) - (90.9234\ u + 141.9164\ u + 2 \times 1.0087\ u)$ [1]

$= 0.1867$ u [1]

(b) Method ① :

$\dfrac{N}{t} = \dfrac{4.00 \times 10^{-5}}{0.235} \times 6.02 \times 10^{23} = 1.025 \times 10^{20}\ s^{-1}$ [1]

$P = \dfrac{N}{t}E = (1.025 \times 10^{20}) \times [0.1867 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2]$ [1]

$= 2.86 \times 10^9$ W [1]

Method ② :

$\dfrac{N}{t} = \dfrac{4.00 \times 10^{-5}}{0.235} \times 6.02 \times 10^{23} = 1.025 \times 10^{20}\ s^{-1}$ [1]

$P = \dfrac{N}{t}E = (1.025 \times 10^{20}) \times (0.1867 \times 931 \times 10^6 \times 1.6 \times 10^{-19})$ [1]

$= 2.85 \times 10^9$ W [1]

Method ③ :

$P = (4 \times 10^{-5}) \times \dfrac{0.1867}{235.0439} \times (3 \times 10^8)^2$ [2]

$= 2.86 \times 10^9$ W [1]

4. (a) mass defect : $\Delta m = \dfrac{173.8}{931} = 0.1867$ u [1]

$\therefore\ 235.0439 = 141.9164 + 90.9234 + 2 \times m_n + 0.1867$ [1]

$\therefore\ m_n = 1.0087$ u [1]

(b) Number of U-235 nuclei $= \dfrac{1.0 \times 10^4}{0.235} \times 6.02 \times 10^{23} = 2.56 \times 10^{28}$ [1]

Energy released $= 2.56 \times 10^{28} \times 173.8$ MeV [1]

$= 4.45 \times 10^{30}$ MeV < **accept** 7.12×10^{17} J > [1]

(c) Total electrical energy released by the fuel rods $= 4.45 \times 10^{30} \times 10^6 \times 1.6 \times 10^{-19} \times 40\%$

$= 2.848 \times 10^{17}$ J [1]

By $E = P\,t$

$\therefore\ (2.848 \times 10^{17}) = (500 \times 10^6)\,t$

$\therefore\ t = 5.70 \times 10^8$ s < **accept** 1.58×10^5 hours **or** 6590 days **or** 18.1 years > [1]

5. (a) The temperature in the Sun's core is so high that the hydrogen nuclei have sufficient large kinetic energy [1]

to overcome the strong electrostatic repulsion between them. [1]

5. (b) $\Delta m = (4)(1.00728) - 4.00150 = 0.02762$ u [1]

$\Delta E = \Delta m c^2 = (0.02762)(1.661 \times 10^{-27})(3 \times 10^8)^2 = 4.13 \times 10^{-12}$ J [1]

OR

$\Delta E = 0.02762 \times 931 \times 10^6 \times 1.6 \times 10^{-19} = 4.11 \times 10^{-12}$ J [1]

(c) Number of hydrogen atoms in 1 kg of hydrogen $= \dfrac{(1)}{(1\times10^{-3})} \times (6.02 \times 10^{23})$

Number of fusion by 1 kg of hydrogen $= \dfrac{(1)}{(1\times10^{-3})} \times (6.02 \times 10^{23}) \times \dfrac{1}{4} = 1.505 \times 10^{26}$ [1]

Energy released by 1 kg of hydrogen $= 1.505 \times 10^{26} \times 4.13 \times 10^{-12}$

$= 6.22 \times 10^{14}$ J <accept 6.14×10^{14} J to 6.28×10^{14} J> [1]

6. (a) ${}^{222}_{86}\text{Rn} \longrightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He}$ [1]

Mass defect = 222.0176 u − (218.0090 u + 4.0026 u) = 0.006 u [1]

Energy released = 0.006 × 931 = 5.586 MeV <accept 5.59 MeV> [1]

(b) The mass ratio of the products is $m_{Po} : m_\alpha = 218 : 4$

By conservation of momentum, the speed ratio is $v_{Po} : v_\alpha = 4 : 218$ [1]

The kinetic energy of the products is $KE_{Po} : KE_\alpha = \frac{1}{2}(218)(4)^2 : \frac{1}{2}(4)(218)^2 = 4 : 218$ [1]

Thus, most of the energy released is given to the α.

(c) By $E = \dfrac{1}{2} m v^2$

$\therefore\ (5.586 \times 10^6 \times 1.6 \times 10^{-19}) = \dfrac{1}{2} \times (4.0026 \times 1.661 \times 10^{-27}) v^2$ [1]

$\therefore\ v = 1.64 \times 10^7$ m s^{-1} [1]

7. (a) ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + {}^{0}_{-1}\text{e}$ <accept ${}^{0}_{-1}\beta$> [1]

(b) (i) Number of atoms of I-131 in 1 kg $= \dfrac{1}{131\times10^{-3}} \times 6.02 \times 10^{23} = 4.60 \times 10^{24}$ [1]

Decay constant of I-131 : $k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{8.02\times24\times3600} = 1.00 \times 10^{-6}$ s^{-1} [1]

Initial activity : $A_o = k N_o = (1.00 \times 10^{-6})(4.60 \times 10^{24}) = 4.60 \times 10^{18}$ Bq [1]

7. (b) (ii) $\Delta m = 130.90612 - 130.90508 - 0.00054 = 5 \times 10^{-4}$ u [1]

$E = (5 \times 10^{-4}) \times (931 \times 10^6 \times 1.6 \times 10^{-19})$ [1]

$= 7.45 \times 10^{-14}$ J [1]

OR

$E = \Delta m c^2 = (5 \times 10^{-4} \times 1.661 \times 10^{-27}) \times (3 \times 10^8)^2$ [1]

$= 7.47 \times 10^{-14}$ J [1]

$P = EA = (7.45 \times 10^{-14})(4.60 \times 10^{18})$

$= 3.43 \times 10^5$ W <accept 3.4×10^5 W to 3.5×10^5 W> [1]

(c) The decay of a radioisotope is determined by the half-life (**OR** decay constant). [1]

It cannot be changed by human factors or surrounding factors. [1]

(d) Any **ONE** of the following : [1]

* Iodine-123 emits γ rays that give less harmful effect to human body.
* The half-life of Iodine-123 is shorter, thus give less harmful effect to human body.
* Iodine-123 emits γ rays that have greater penetrating power to be detected outside the human body.

8. (a) ${}^{4}_{2}\text{He} + {}^{9}_{4}\text{Be} \longrightarrow {}^{12}_{6}\text{C} + {}^{A}_{Z}Q$ [1]

$A = 4 + 9 - 12 = 1$ and $Z = 2 + 4 - 6 = 0$ [1]

Q is a neutron [1]

(b) (i) $E = Pt$

$= (500 \times 10^6)(1 \times 24 \times 60 \times 60)$ [1]

$= 4.32 \times 10^{13}$ J [1]

(ii) Unit of electrical energy $= \dfrac{4.32\times10^{13}}{3600000}$ [1]

$= 1.2 \times 10^7$ kWh [1]

Cost $= 1.2 \times 10^7 \times \$ 0.9$ [1]

$= \$ 10\,800\,000$ [1]

(iii) Electrical energy produced by 1 kg of uranium $= 5.6 \times 10^{12} \times 30\%$ [1]

$= 1.68 \times 10^{12}$ J [1]

(iv) Mass of uranium fuel used in one day $= \dfrac{4.32\times10^{13}}{1.68\times10^{12}}$ [1]

$= 25.7$ kg [1]

8. (c) **Agree** [1]

Reasons : (any **THREE** of the following) < accept other reasonable answers > [3]

* Reserves of oil and coal are limited.
* Nuclear energy is cheaper.
* Nuclear energy causes less pollution.
* Nuclear energy does not produce greenhouse gases.

OR

Disagree [1]

Reasons : (any **THREE** of the following) < accept other reasonable answers > [3]

* The capital investment of a nuclear plant is high.
* The disposal of radioactive waste causes a serious problem.
* If there is accident, the damage to public is large.
* Some other resources of energy may be used, e.g. solar energy.

9. (a) When a neutron is captured by a Uranium-235 nucleus, the nucleus undergoes fission. [1]

It then splits into two smaller nuclei and together with some fission neutrons. [1]

During the fission, large amount of energy is released. [1]

(b) (i) These isotopes are produced as the **by-products** [1]

of the **fission** of the Uranium-235. [1]

(ii) Radioactive is used to describe an unstable nucleus [1]

that may emit α, β or γ radiation to form a more stable nucleus. [1]

(iii) Metal cans are used since β radiation cannot pass through the metal. [1]

(iv) Number of half-lives $= \dfrac{200}{25} = 8$ [1]

Initial activity $= 400 \times 2^8$ [1]

$= 102400$ Bq [1]

(v) Decay constant : $k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{25 \times 365 \times 24 \times 3600} = 8.79 \times 10^{-10}\ s^{-1}$ [1]

By $A_o = k N_o$ [1]

$\therefore\ (102400) = (8.79 \times 10^{-10})\, N_o$

$\therefore\ N_o = 1.16 \times 10^{14}$ [1]

(c) ① Nuclear fusion can only occur under very high temperature that is not easy to achieve. [1]

② No physical container can withstand the high temperature that fusion occurs. [1]

10. (a) Any ONE of the following : [1]

* cosmic radiation from space
* radiation from rocks
* radiation from air
* radiation from food
* radiation from human bodies

(b) (i) $x = 4$ [1]

(ii) Mass defect $= 235.0439 - (136.9071 + 94.9399 + 3 \times 1.0087) = 0.1708$ u [1]

Energy released $= 0.1708 \times 931$ MeV $= 159$ MeV [1]

(iii) Activity of the sample after 350 years :

$A = (1.2 \times 10^6) \times (\frac{1}{2})^{350/30}$ $\therefore\ A = 369$ Bq [1]

Since the activity is larger than 200 Bq, the claim is correct. [1]

OR

$(200) = (1.2 \times 10^6) \times (\frac{1}{2})^{t/30}$ $\therefore\ t = 377$ years [1]

Since the time for the activity to drop to 200 Bq is longer than 250 years, the claim is correct. [1]

11. (a) ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$ (**OR** ${}^{4}_{2}He$)

< atomic number and mass number of α correct > [1]

< atomic number and mass number of Rn correct > [1]

(b) Mass defect :

$\Delta m = 226.0254 - 222.0176 - 4.0026 = 0.0052$ u [1]

Energy released :

$E = 0.0052 \times 931 = 4.84$ MeV [1]

(c) Mass of radium $= 5\ \mu g$

Number of radium atoms in this source :

$N = \dfrac{5 \times 10^{-6}}{226} \times 6.02 \times 10^{23} = 1.332 \times 10^{16}$ [1]

Decay constant :

$k = \dfrac{\ln 2}{t_{1/2}} = \dfrac{\ln 2}{1600 \times 365 \times 24 \times 3600} = 1.374 \times 10^{-11}\ s^{-1}$ [1]

Activity :

$A = kN = (1.374 \times 10^{-11}) \times (1.332 \times 10^{16}) = 1.83 \times 10^5$ disintegrations per second [1]

< accept 1.83×10^5 Bq > < accept 1.82×10^5 Bq >

12. (a) $\Delta m = 2.014102 + 3.016049 - 4.002602 - 1.008665 = 0.018884$ u [1]

$E = 0.018884 \times 931 = 17.58$ MeV < accept 17.6 MeV > [1]

OR

$E = 0.018884 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2 = 2.823 \times 10^{-12}$ J [1]

(b) (i) To overcome the electrostatic repulsion between the two (positive) nuclei, [1]

the temperature must be very high so that the ions has sufficient kinetic energy to come close to each other. [1]

(ii) $E_k = \frac{3}{2} \cdot \frac{R}{N_A} \cdot T$

$\therefore (0.2 \times 10^6 \times 1.6 \times 10^{-19}) = \frac{3}{2} \cdot \frac{(8.31)}{(6.02 \times 10^{23})} \cdot T$ [1]

$\therefore T = 1.55 \times 10^9$ K

Order of magnitude of temperature $= 10^9$ K < exact answer not accepted > [1]

13. (a) (i) $x = 3$ 1A | 1

(ii) More neutrons are produced in each fission for triggering further fissions, i.e. $x > 1$. 1A | 1

(b) (i) $m = m_0 e^{-kt}$

$k = \frac{\ln 2}{t_{1/2}}$ $(= 9.846 \times 10^{-10}\ \text{yr}^{-1})$

$0.06 = m_0\, e^{-\ln 2 \times \left[\frac{2 \times 10^9}{7.04 \times 10^8}\right]}$ 1M OR $0.06 = m_0 \left(\frac{1}{2}\right)^{2\times10^9 / 7.04\times10^8}$

$m_0 = 0.429882832$ (kg) ≈ 0.430 (kg) 1A | 2

(ii) $\frac{0.430}{13.556 + 0.430} = 0.03073691 \approx 3.1\,\% > 3\%$

Thus natural nuclear fission was possible. 1M/1A | 1

(c) Underground water might run dry. 1A

OR Energy released by fission drys up the underground water. 1A

Therefore, fission might stop without slow neutrons. 1A | 2

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